McMILLAN

Duty Trial of a 40,000,000-Gal.
Duplex Triple Expansion
Worthington Pumping Engine

Mechanical Engineering

B. S.

1909

DUTY TRIAL OF A 40,000,000-GAL. DUPLEX TRIPLE EXPANSION WORTHINGTON PUMPING ENGINE

BY

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THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE

IN MECHANICAL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

OF THE

UNIVERSITY OF ILLINOIS

Presented June, 1909

UNIVERSITY OF ILLINOIS

JUNE 1, 1909

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

EUGENE CAMPBELL MC.MILLAN

ENTITLED DUTY TRIAL OF A 40,000,000-GAL. DUPLEX TRIPLE EXPANSION WORTHINGTON PUMPING ENGINE

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE

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HEAD OF DEPARTMENT OF MECHANICAL ENGINEERING

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Introduction

While a pump is a very simple mechanism and does not seem a very important factor in the world's progress, yet when one stops to enumerate the different occupations that can be carried on without the aid of a pump in some form or other, he is at once surprised at the smallness of the figure. Were it not for the pump the live-stock on our farms would perish in the summer , while the city would never reach any great size until fire would claim it as a victim. It is this wide scope of utility that has developed the pump into one of the most important of machines, and without it a great handicap would be placed on every industry.

While the pump is one of the most important pieces of machinery, yet in attaining its present stage of development it has presented to engineers some of the most difficult problems. It is the completeness of the solution of these problems in the design and operation of the Henry R. Worthington forty-million gallon pumping engine installed in the Springfield Avenue Pumping Stations of the city of Chicago, that prompted the presentation of this paper.

Part I

History of the Development of the Pumping Engine

Considering modern machinery in its relative importance today, it hardly seems natural that the pumps should be among the last to make its appearance. The history of pumping machinery dates from the year 200 B.C., there being no mention of such machinery previous to that time. In early days the man who had a water supply in the form of a well was considered wealthy and the manner of drawing the water to the surface was a matter of secondary consideration it generally being accomplished by means of a cord and buckets or some similar means. This perhaps accounts for the fact that in Hero's "Pneumatics" we find the invention of the pump preceeded by that of the slide valve, the spindle valve, the common clack valve, illustrating the application of a metallic piston to a metallic cylinder , and nearly one hundred other inventions.

While it is impossible to give in this brief discussion all of the inventions produced in the development of the pump of today , yet a few of the main steps will be set forth here ,. The first pump of which we have any record, described in Hero's "Pneumatics" embodies the present principal of valves; i.e., an inlet and outlet valve to a cylinder in which a piston works. The pumps had two cylinders which were single acting, the pistons being connected to a rocker arm so that one piston at a time discharged water into the common discharge pipe. While

the pump had this early date for its birth, yet it was not until the beginning of the seventeenth century that the true principal of its action was understood. Until this time no attempt had been made to discover the reason why water rose upwards under the piston. In the year 1641 the Duke of Florence when pump maker to his Royal Highness, complained that the water would not rise more than thirty two feet. Galileo was applied to for a solution of the problem but failed, and it was a short time after, that one of his pupils, Toricelli, came to the conclusions that atmospheric pressure counter poised the thirty -two feet column of water. Experiments in 1643 proved his supposition correct, as well as establishing the principal of our present barometer.

At the beginning of the sixteenth century we do not find any very great steps taken in the development of pumps over the simple one of Hero's time. London seems to claim the honor of having the first water works of any consequence. It was in the year 1581 that Peter Maurice was granted a lease to erect an engine within the first arch of the London Bridge, for the purpose of supplying the city with water. His pumping machinery consisted of an undershot waterwheel, connected to pumps; which, when the tide flowed quickly, had a capacity of pumping at the rate of two and one-half million gallons per twenty-four hours.

Perhaps the next step worthy of note, is that of the invention of the stuffing box. All pumps considered so far have been of the single acting type. In the year 1675 Sir Samuel Morland invented the plunger pump, the main feature of

which was the stuffing box. This not only marks one of the main steps in pump design, but it also made possible the steam engine in its present form.

In the year 1732 M. Demour a Frenchman proposed to raise water by putting into rapid motion pipes spreading at the top like a V. This was the first step in the development of our present form of centrifugal pumps. M. Demour in the operation of his pumps placed the apex of the cone of pipes in water and then by revolving at a high rate of speed the centrifugal force overcame gravity, and the water rose in the pipes and was delivered at a higher level.

While pumps of today do not differ materially from those of the sixteenth and seventeenth centuries, yet there is a marked change in the mode of driving them. The mine pumps of an earlier day were run mostly by horse-power and it was not until the latter part of the eighteenth centry that steam was used to any great extent to run pumps. The first type of steam propelled pumps was of the shaft and flywheel pattern, where an engine was used to turn the crank on one end of the shaft while the pump was operated from the other, with the fly-wheel between. There was the objection to this type of pump that the delivery was not constant, but fluctuated throughout the stroke. As the piston came to rest at each end of the stroke, the whole column of water must also stop and start with it, and in this manner a great deal of energy was lost. This was practically over come for the time being by means of an air chamber placed in the delivery pipe which acted as an accumulator storing up and giving out energy during

each stroke of the pump .

Mr. Jonathan Dounton of Blackwell London in the year 1825 overcame this feature in another manner on the pumps that were used in the British Navy at that time. He used the shaft and flywheel type of pump but had three pistons working in the one cylinder. The three piston rods telescoped one another and were attached to three separate cranks on the shaft , set at angles of 120° . Thus he had one piston rising all the time so that nearly a constant flow of water from the mains resulted. This type of pump was used for many years by the Britons and proved a most successful machine.

The shaft and fly-wheel pump however had its disadvantage in that the power must be transmitted to the shaft and from there to the pump . This was not a very efficient method and attempts were being made to eliminate this feature when Henry R. Worthington came out with his direct connected pump and engine. That is, with the pump piston on one end of the piston rod and the steam piston on the other. In the first pump put out, he did not gain much, if any , in efficiency over the other forms of pumps, due to the fact that full steam pressure was required throughout the entire stroke and thus the expansive force in the steam could not be utilized. While it was inefficient, yet it was in a different manner , and having over come some difficulties, it gave a new line along which to work. This type of pump had been long looked for, but had been rather slow in its development due to the difficulty of obtaining a positive valve motion. This feature was overcome by Worthington on his single cylinder pump , and later in a

much simpler manner upon the duplex pump where the action of the piston of one pump controlled the valve action of the other.

This type of pump with all of its modern improvements is the pump of today as we see it in all of its varied forms. While the shaft and fly-wheel pump is still used in a great many places and the centrifugal pump has its field, yet none of them serve in as many places as does the direct acting type.

Part II

The Development of the Henry R. Worthington Pumping Engine.

It is safe to say that no form of steam pump is in such extensive use today as the direct acting steam pump, and when this is traced to its origin, we find it in the mind of one of the laborers on a canal boat. Mr. Worthington was a young man 23 years of age, with no special training, and a common laborer on one of the boats of our inland water-ways . The canal boats in their progress had to go through locks at various points, and as the pumps for supplying water to the boilers were directly connected to the engines that propelled the boat, it made it necessary for one man to pump the water by hand while the engines were idle. This was the time that all of the extra labor was needed to help operate the lock gates etc., so it entered young Worthingtons mind to make the pump automatic.

Worthington received the first patent on his pump in 1841. The pump while crude in some respects was very complete in others. The primary objects for which it was designed was that of automatically supplying water to a steam boiler. The pump and boiler were so arranged together with floats and levers, that as soon as the water level in the boiler fell to a certain point, the pump started up and continued to run until the maximum level was reached, when it was automatically stopped. This form of pump seemed to work perfectly satisfactorily but the automatic boiler supply attachment soon lost favor in that it

proved as dangerous as it seemed reliable. The pump itself was far from perfection . The first objection lay in the fact that the mass of water being moved came to rest at the end of each stroke, and when it was again started, severe strains were brought upon all parts of the pump and piping. Worthington did not loose sight of this point in his search to improve the original, and it was not many years until he placed what is known as the Worthington Direct-Acting Duplex Pump on the market. This pump was much simpler than the single pump in that the action of one piston controlled the valve motion of the other, which insured a positive action and caused one piston to be a half stroke ahead of the other. This latter feature eliminated the straining action on the pump parts , and gave nearly a steady delivery.

With this improvement the direct acting pump came into quite general use for all small work such as feeding boilers. However there was one other point in which this pump was deficient and which prevented its use where any great quantity of water was to be pumped or where fuel was high in price. The pump constructed as it was required full steam pressure behind the piston for the full stroke, for if there was any diminution of steam in volume or pressure at any point in the stroke the pump came to a standstill. This made the pump very uneconomical in its use of steam, as none of the expansive force present would be utilized. This was first overcome by means of a second steam cylinder placed in line with the first, and having a volume about four times that of the first cylinder. The steam was used in the small cylinder, from which it exhausted behind the piston of the larger and was used again. With this improvement and

other small changes in design the direct acting pump was at last placed in position to compete with the rotative pumps which had held unchallenged supremecy in all of the larger pumping plants of the world.

As the size of water-works plants increased the sudden stopping and starting of the column of water being moved grew to be such an important item, that the fly-wheel pumps soon became inadequate. The direct acting duplex pump eliminates this feature so that with the slight aid of an air chamber in the discharge mains. great masses of water may be forced through long mains without the least unnecessary strains. While the direct acting pumps accomplished many things it still was objectionable in that the steam could not be cut off and allowed to expand in the different cylinders. It was nearing the level of the fly-wheel pump in this respect, yet the latter could store up energy in the fly-wheel at the beginning of the stroke and give it out on the last half , thus excelling the direct acting pump in economy. Attempts were made to attach this feature in the form of a flywheel to the direct acting pump, but it was as a rule at the expense of the much desired steady delivery.

The solution of this problem was at last rendered by the son of the inventor of the direct acting pump. The one idea on which he worked was that the indicator card taken from the water cylinder was practically a rectangle, and that to use the expansive force of the steam he must have an excess pressure at the beginning of the stroke which could be stored up and given out as the steam expanded. Were it not stored up the

excess pressure would be transmitted directly to the water plunger which would result in uneven water pressure throughout the stroke, and the disastrous feature of unsteady pressure in the mains would again be introduced. This energy due to the excess pressure at the beginning of the stroke was stored up in what are called compensating cylinders. To the crosshead of the pump are attached two oscillating cylinders so set that when the piston rod is at the center of its stroke the cylinders which turn on trunions, are at right angles to the piston rod. The compensating cylinders are connected through their hollow trunions to an accumulator. The pressure on the plunger in the cylinders is governed by this differential type of accumulator. This accumulator is a vertical cylinder of two different bores. The smaller bore is at the bottom, and is connected to the trunions of the oscillating cylinders by piping . The upper end, which has the larger bore is connectd to the air chamber in the delivery mains. In this accumulator is one common piston the one end of which fits the small bore and the other the large bore of the cylinder. The oscillating cylinders piping and small end of this cylinder are filled with water, while the upper end and piping to the air chamber are filled with air. Thus we have the pressure on the plungers in the compensating cylinders is equal to the pressure per square inch in the water mains multiplied by the ratio of the two piston areas in the accumulator.

The action of this new type of "fly-wheel" as it is some times called is as follows : During the first part of the stroke while there is excessive pressure in the steam cylinders the plungers of the compensating cylinders are being forced

in so that energy is being stored up. As soon as the pump piston has passed the middle of the stroke, the steam has been cut off in the steam cylinders and starts to expand, while the compensating cylinders are starting to give out the energy that was stored during the first half of the stroke. Tests have shown this type of "fly-wheel" to be perfectly satisfactory. With this one and perhaps most important steps of all in the development of the direct-acting, pumping engine, this type of machine has risen to a position equal if not superior to any. This feature just described is fully covered by the patents in the hands of the International Steam Pump Co. of New York and until it becomes public property, the performance of this pump will probably not be excelled.

Part III

Results of Previous Tests of Worthington Pumping Engines

Where located	Capacity per 24 hours in million gallons	Date	Dimensions of Engine: Steam Cylinders	Dimensions of Engine: Water Cylinders	Duty in Millions of Foot pounds.
Brooklyn, N.Y.	3	1885	36" x 18" x 26"	17.3" x 26"	113.4 per 112 lbs. coal
New Bedford, Mass.	5	1886	36" x 18" x 26"	24" x 26"	102 " 100 " "
Montreal, P.Q.	10	1888	28.75" x 57.5" x 50"	31.5 x 50"	102 " " " "
Davenport Ia.	5	1888	21" x 42" x 36"	19.5" x 36"	121.8 " " " "
Hampton Eng.	20	1888	27" x 54" x 43"	40 x 43"	106.5 " 112 " "
London Eng.	9	1888	27" x 54" x 39.5"	28" x 39.5 "	106.5 " " " "
Minneapolis, Minn.	30	1890	33" x 66" x 49.7 "	32.6 x 49.7"	130.5 " 100 " "
Hammersmith Eng.	7	1890	22" x 43" x 48"	19.5" x 48"	116 " " " "
Hyde Park Chicago	12	1890	33" x 66" x 49.8	33 " x 49.8	108.5 " " " "
Memphis Tenn.	30	1891	30" x 60" x 48"	27" x 48"	117.3 " " " "
Birmingham AlA.	5	1891	28.75" x 57.5" x 50"	19" x 50"	127.8 " " " "
Syracuse N.Y.	10	1891	21" x 42" x 36"	27.5" x 36"	109 " 1000 " Steam
Nashville Tenn.	10	1891	41" x 82" x 60"	26.5" x 60"	95.6 " 100 " coal
Lowell Mass.	10	1892	25" x 50" x 38"	27.5" x 38"	116.2 " Million B.T.U.
Port Perry Penn.	3	1892	15" x 33" x 57.5"x37.8"	16.5" x 37.8"	134 " 1000 lbs. steam
Erie Penn.	12	1893	33" x 66" x 49.75"	29" x 49.75	127.5 " 100.0 " coal
New Haven Conn.	10	1896	18" x 36" x 36"	26" x 36"	108.2 " 1000 " steam
Hampton Eng.	16.5	1896	18.5" x 29" x 45" x60	29" x 60"	113.8 " " "
			Pumps using superheated steam		
Montreal	12	1908	21" 35" x 60" 36 (superheat 209° F)	29.5" x 36	177.3 " " " "
New York	15	1904	16" x25" x46" x36 (superheat 80° F)	31" x 36"	155 " " " "
Central Park Station Chicago Engine F1200 20 " "1201 20		1903	21" x33" x60" x50" (superheat 87.2° F)	34.5" x 50"	161.6 " " " "

Central Park Station
Chicago

Engine	E 1201	20	1903	21" x 33" x 60" x50" (superhea t 63.4° F)	34.5" x 50"	156.6 per 1000 lbs. steam
"	E 1201	20	1903	21" x 33" x 60" x50" (superheat 71.2° F)	34.5" x 50"	157.1 " " " "
"	E 1201	20	1902	21" x 33" x 60"x50" (superheat 126.7°F)	34.5" x 50"	157.0 " "" " "
"	E 1201	20	1902	21" x 33" x 60"x50" (superheat 142.8°)	34.5" x 50"	163.0 " " " "
"	E 1201	20	1902	21" x 33" x60" x50" (superheat 154°F)	34.5" x 50"	174.7 " " " "

Part IV

Report of test on Engine E 2025 in the Springfield Avenue Pumping Station of Chicago .

In this section is submitted a report of the duty trial on the forty-million gallon duplex, triple expansion, Worthington pumping engine located in the Springfield Avenue Pumping Station in Chicago.

Object of Trial, - This trial was conducted by Wm. Swanhausser for the Henry R. Worthington Co., Thomas T. Johnston for the city of Chicago and J. C. Thorpe as the disinterested engineer. The object of the trial being to determine the duty developed per 1000 pounds of steam consumed by the engine when operating against a head of not less than 120 feet, with a steam pressure of not less than 140 pounds per square inch at the throttle, the steam being superheated to at least 140 Farenheit. It was also the object of this trial to determine whether or not the pump would deliver 40 000 U.S. gallons per 24 hours under the above stated conditions.

Description of Engine, - The engine was built and installed by the Henry R. Worthington Co., of New York in the year 1904. It is a vertical, duplex, triple expansion, direct connected pumping engine of the high duty type, having six steam cylinders twenty-seven(27) inches forty-two(42) inches and seventy-six (76) inches in diameter ; two double acting , outside packed water plungers forty-five (45) inches

in diameter, direct connected to the steam cylinders all of which have a nominal stroke of sixty(60) inches. The engine is fitted with the Worthington Improved Corliss Steam Valve Gear , and also has the Worthington High Duty Attachment.

The engine is equipped with a surface condenser , located in the pump suction pipe, having a cooling surfacr of eighteen-hundred (1800) square feet. The air pump, having two double acting plungers twenty (20) inches in diameter and a stroke of sixteen (16) inches, is attached to and driven by the main pump.

The following are the principal dimensions of the engine:

Number of cylinders	6
Diameter of high pressure cylinders inches	27
Diameter of intermediate pressure cylinders inches	42
Diamter of low pressure cylinders inches	76
Number of water plungers	2
Diameter of water plungers inches	45
Nominal stroke of all pistons and plungers inches	60
Diamter of piston rods ; one 4" ; two 4" ; and one 6" .	
Area of H. P. piston (sq. in.)	566.27
" " I. P. " " "	1366.60
" " I. P. " " "	4507.31
" " Plungers " "	1577.87
Diameter of air piston of accumulator inches	42
" " water plunger of accumulator inches	11
" " compensating cylinder plungers inches	9
Clearance at contact in high pressure cylinder (%)	2.0
" " " " intermediate pressure cylinder (%)	1.5
" " " " low pressure cylinder (%)	1.0
Clear opening through suction valves, each deck (sq. in.)	1200

Clear opening through discharge valves, (square inches) 1200

Clear opening through suction pipe (square inches) --------1840

Conduct of Trial - The trial was made October 1 and 2, 1908. The trial beginning at 1:45 o'clock P.M. October 1 and continuing for twenty-four hours (24) ending at 1:45 o'clock P.M. October 2.

Throughout the trial readings were taken every fifteen (15) minutes of the steam pressure, receiver pressure, reheater pressure, jacket pressure, and vacuum. At intervals of thrity (30) monutes indicator cards were taken from the steam cylinders.

Indicator cards were taken from only one set of cylinders at a time . During the first six hours of the test cards were taken from the three left cylinders. During the second six hours from the right three cylinders, the third six hours from the left and the fourth six from the right. Crosby inside spring indicators were used. An eighty (80) pound spring was used on the high pressure cylinder, a twenty (20) pound spring on the intermediate pressure cylinder, and a ten (10) pound spring on the low pressure cylinder. The springs were calibrated before the test and were found to be correct. Samples of the cards taken are included in this report.

During the trial the water of condensation from the condenser , and also from the jacket and reheater drains was collected in large barrels and carefully weighed.

The temperature of the water pumped, of the condensed steam and of the superheat were taken at regular intervals throughout the test.

The revolutions were recorded by a counter connected to

the valve motion of the engine,.

The pressure in the discharge main was measured with a Bourdon Gauge which was tested with a dead weight tester both before and after the trial and found to be correct. The elevation of this gauge with reference to the Chicago Datum was determined with an engineers level before the trial. The depth of water in the wet well below the Chicago Datum was shown by a dial connected to a float. This apparatus which is used in the every day operation of the plant, was checked up the day before the trial and several times during the trial and found to be correct. The total head then against which the pump works is the sum of the water pressure gauge reading in feet, the elevation of the same gauge , and the reading of the wet-well dial.

Sample Calculations

(1) Average revolution of engine per minute

$$\frac{\text{Total revolutions}}{24 \times 60}$$

$$\frac{25605}{24 \times 60} = 17.77$$

(2) Average piston speed-feet per minute = Average stroke (ft.) x 2 x 17.77

= 5.124 x 2 x 17.77

= 181.964

(3) Average plunger displacement per revolution (cu.ft.)

= Area of plunger (sq.ft.) x 4 x stroke (ft)

$= (\pi \times \overline{1.875}^2 - .0873) \times 4 \times 5.124$

= 224.399

(4) Average plunger displacement per revolution gallons

= 224.399 x 7.481

= 1678.5

(5) Average plunger displacement per revolution (pounds).

= 224.399 x 62.4

= 14002.5

(6) Average plunger displacement per 24 hours (cu.ft.)

= (3) x 25605

= 224.399 x 25605

= 5745736

(7) Average plunger displacement per 24 hours (gals)

= (4) x 25605

= 1678.5 x 25605

= 42978105

(8) Average plunger displacement per hour (pounds)

$= (5) \times 25605$

$= 14002.5 \times 25605$

$= 358,533,926$

(9) Net work delivered per 24 hours foot pounds

$= (8) \times 123.32$

$= 358533,926$

$= 44,214,403,754$

(10) Net delivered horse-power

$$= \frac{9}{24 \times 60 \times 33000}$$

$$= \frac{44214403754}{24 \times 60 \times 33000}$$

$= 930.43$

(11) Steam used per net delivered horse power per hour(lb)

$$= \frac{252415}{24 \times 930.43}$$

$= 11.30$

(12) I. H. P..

$= 993.58$

(13) Mechanical Efficiency

$$= \frac{(10) \quad 930.43}{(12) \quad 993.58} = .9392$$

$= 93.92\ \%$

(14) Duty per 100 pounds steam used (foot pounds)

$$= \frac{(9)}{252415} \times 1000$$

$$= \frac{44214403754}{252.415}$$

$= 175165516$

The following is a record of the observations and the data and results derived therefrom.

Table of Results

Number of Engine	E 2025
Date	10 - (1 - 2) - 08
Duration of trial (hrs).	24
Steam pressure at throttle (lbs)	141.6
" " on L. P. Jackets (lbs)	12.8
" " " reheater coils (lbs)	103.0
Vacuum in condenser (ins. mercury)	26.71
Barometer (lbs)	14.44
Balancing pressure pounds	106.0
Delivery pressure (guage reading ft.)	86.68
Elevation of gauge above Chicago Datum (feet)	29.34
Elevation of water in wet-well below Chicago Datum (ft.)	7.3
Total head on pump (ft.)	123.32
Temperature of water pumped (°F)	60.7
Number of degrees superheat in steam at throttle (°F)	182.0
Total condensed steam from air pump and jackets (lbs)	252415.0
" revolutions of engine (24 hrs)	25605
Average revolutions of engine per minute	17.77
" length of stroke (ins)	61.487
" " " " (ft.)	5.124
" piston speed ft per minute	181.964
" plunger displacement per revolution (cu.ft.)	224.399

Average plunger displacement per rev.	(gals.)	1678.5
" " " " "	(lbs.)	14002.5
" " " " 24 hrs.	(cu.ft.)	5745736.0
" " " " " "	(gal)	42978105
" " " " " "	(lbs)	358533926
Net work delivered per 24 hours foot	pounds	44214403754
" delivered horse-power		930.43
Steam used per net delivered horse-power per hr.	(lb.)	11.30
Indicated horse-power I.H.P.		993.58
Mechanical Efficiency		93.92
Duty per 1000 pounds steam used	(foot pounds)	175165516

Part V

Conclusions

When this test was run it was purely commercial in character, the object being to determine whether or not the engine would develop the guaranteed duty, cosequently the data necessary for a complete report as to heat balance etc. was not taken. We can, however, by taking the results of this test together with the tabulated list of previous tests , draw some interesting general conclusions. By comparing the duty of the tabulated list of pumps it will be seen that the pumps using superheated steam in every case develope a higher duty than those running on saturated steam. Another very noticeable feature is that the higher degree of superheat, within the limits of available data, the higher the duty delivered, as is shown by the curve, plate number 3 . The points on this curve were taken from the data from the eight pumps included in the previous list, together with the results of the present test. It is to be expected that the points would not lie on a true curve as these pumps are located in different places, and were tested at different times under varying conditions, and no "correction curves" are presented whereby the data might be reduced to a common basis of pressure, speed, vacuum, and superheat. As stated above, it will be noticed that there is an increase of duty with an increase of superheat, but also, that the increment of increased duty grows smaller as the degree of superheat approaches the limit of the curve. This would indicate that there is an increase in economy of operation by

superheating up to 175°F after which the gain in duty practically ceases. The reason for this is probably that at the higher degrees of superheat, the steam goes through the three cylinders and is still slightly superheated when exhausted.

The fact that such a wide variation in conditions exists for the different points on the curve, and that there still exists this relation between superheat and duty, only goes to prove that the conclusions drawn may be relied upon.

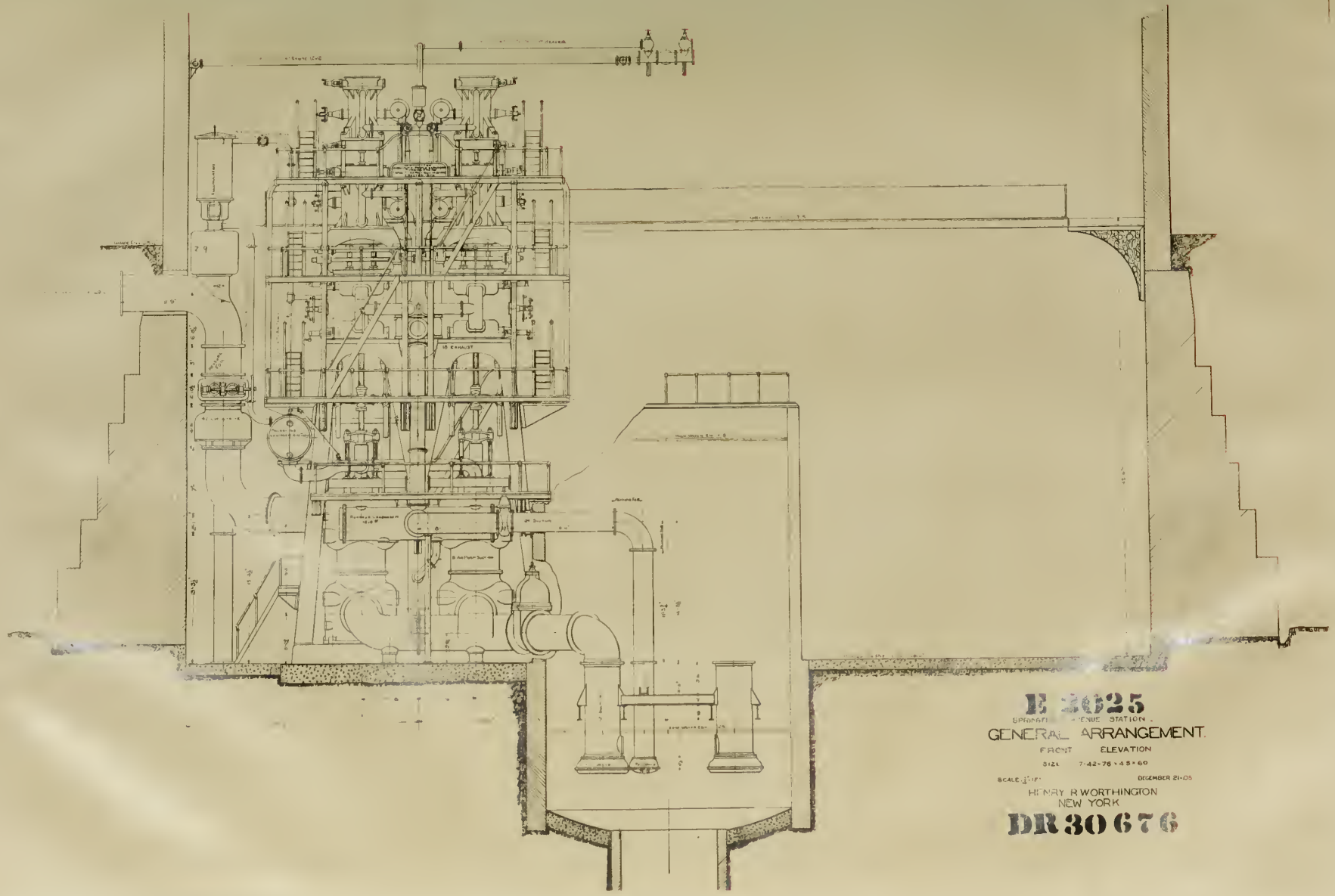
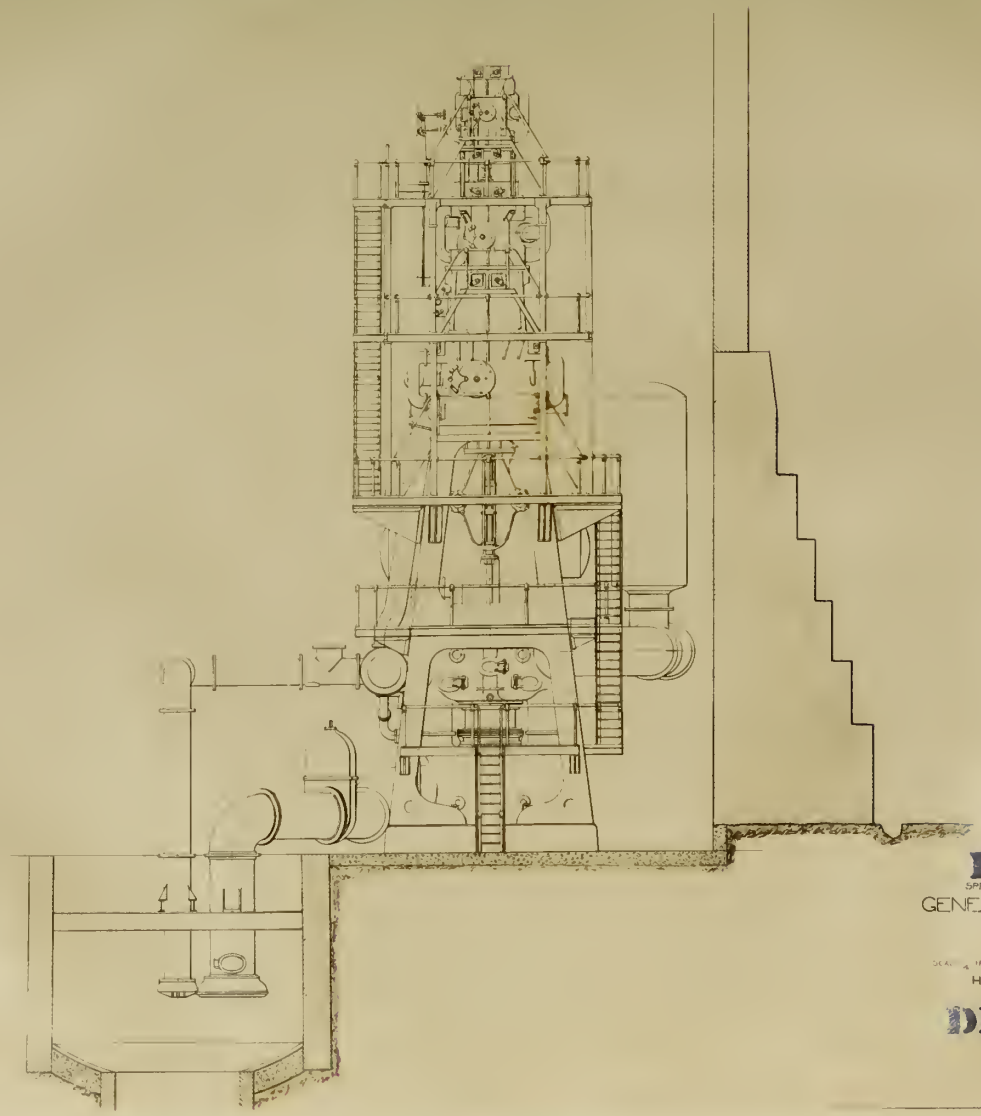

E 3025
GENERAL ARRANGEMENT.
FRONT ELEVATION
SIZE 7-42-76 × 45 × 60
DECEMBER 21-05
HENRY R WORTHINGTON
NEW YORK
DR 30 676

PLATE I.



E. 2025

SPRINGFIELD AVENUE STATION

GENERAL ARRANGEMENT

SIDE ELEVATION.

SIZE 27-42-76+45+60

SCALE 1/4" = 1FT DECEMBER

HENRY R. WORTHINGTON
NEW YORK

DR 30677

PLATE II.

PLATE III.

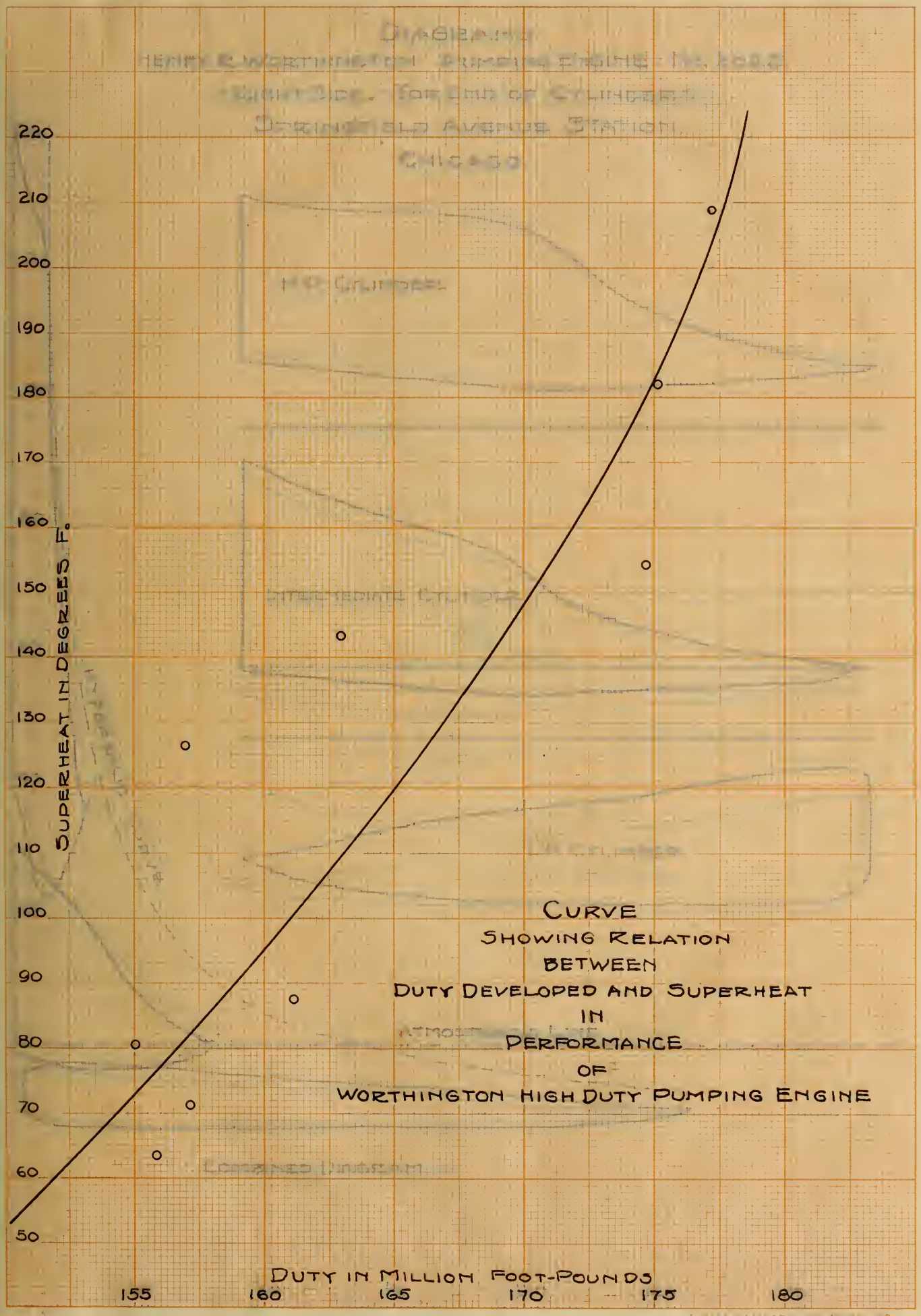

SUPERHEAT IN DEGREES F.
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
DUTY IN MILLION FOOT-POUNDS
155
160
165
170
175
180
CURVE
SHOWING RELATION
BETWEEN
DUTY DEVELOPED AND SUPERHEAT
IN
PERFORMANCE
OF
WORTHINGTON HIGH DUTY PUMPING ENGINE

PLATE III.

Curve
Showing Relation
Between
Duty Developed and Superheat
in
Performance
of
Worthington High Duty Pumping Engine
Superheat in Degrees F°
Duty in Million Foot-Pounds
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
155
160
165
170
175
180

PLATE IV.

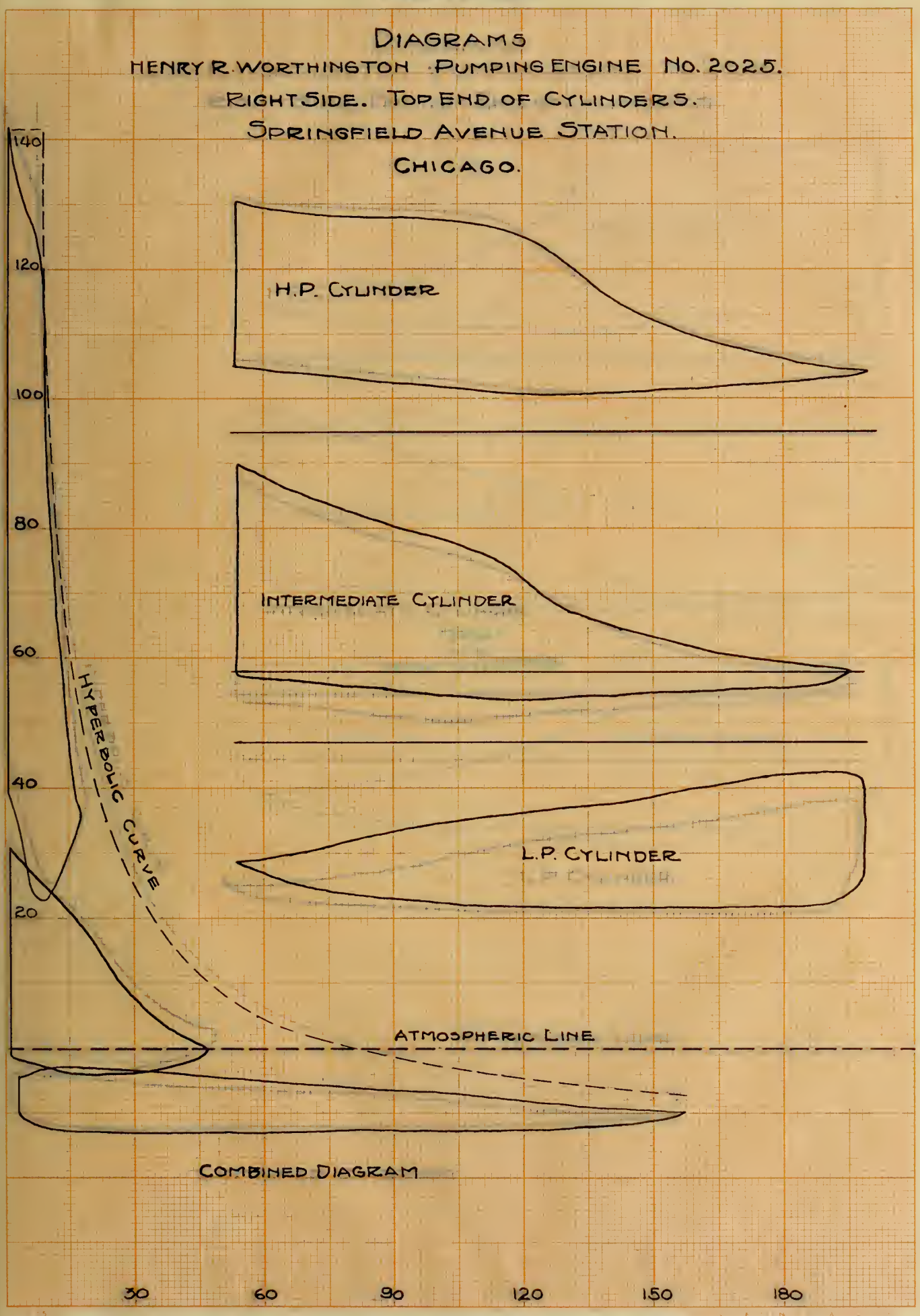

DIAGRAMS
HENRY R. WORTHINGTON PUMPING ENGINE No. 2025.
RIGHT SIDE. TOP END OF CYLINDERS.
SPRINGFIELD AVENUE STATION.
CHICAGO.
140
120
100
80
60
40
20
H.P. CYLINDER
INTERMEDIATE CYLINDER
L.P. CYLINDER
HYPERBOLIC CURVE
ATMOSPHERIC LINE
COMBINED DIAGRAM
30
60
90
120
150
180

PLATE IV.

DIAGRAMS

HENRY R. WORTHINGTON · PUMPING ENGINE No. 2025.

RIGHT SIDE. TOP END OF CYLINDERS.

SPRINGFIELD AVENUE STATION.

CHICAGO.

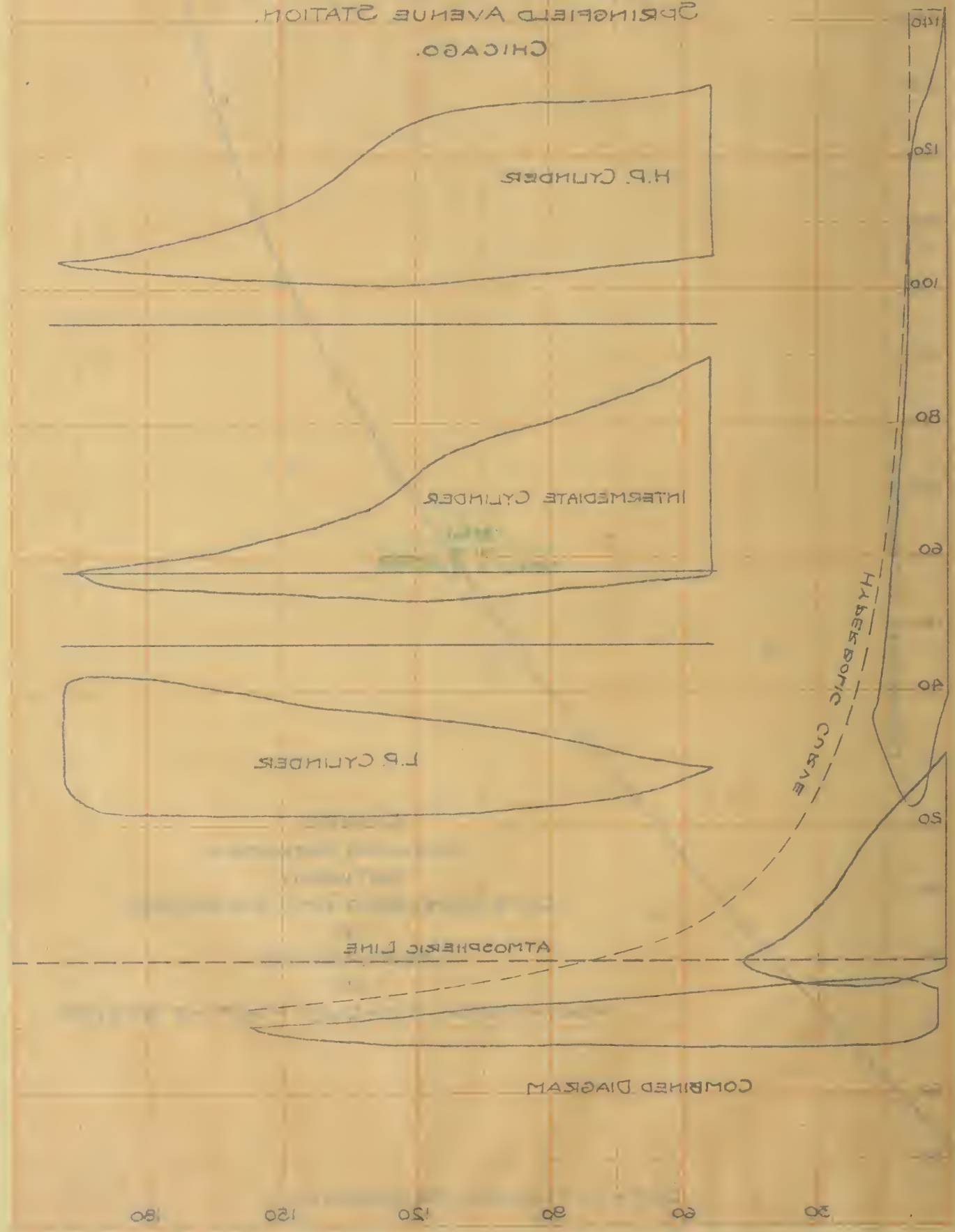


PLATE V.

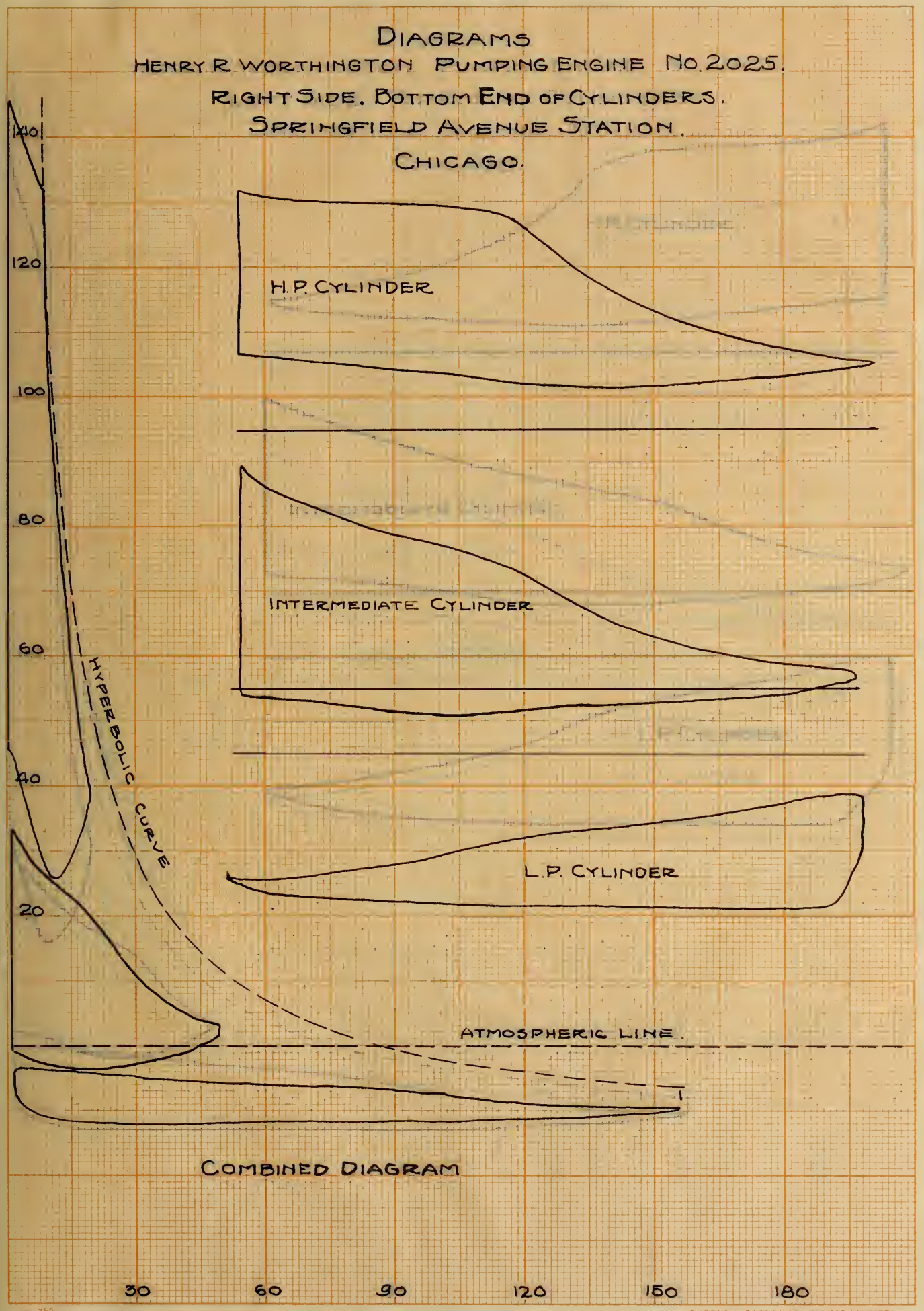

DIAGRAMS
HENRY R. WORTHINGTON PUMPING ENGINE NO. 2025.
RIGHT SIDE. BOTTOM END OF CYLINDERS.
SPRINGFIELD AVENUE STATION.
CHICAGO.
140
120
100
80
60
40
20
H.P. CYLINDER
INTERMEDIATE CYLINDER
L.P. CYLINDER
HYPERBOLIC CURVE
ATMOSPHERIC LINE.
COMBINED DIAGRAM
30
60
90
120
150
180

PLATE V.

DIAGRAMS

HENRY WORTHINGTON PUMPING ENGINE No 2.025.

RIGHT SIDE. BOTTOM END OF CYLINDERS

SPRINGFIELD AVENUE STATION.

CHICAGO.

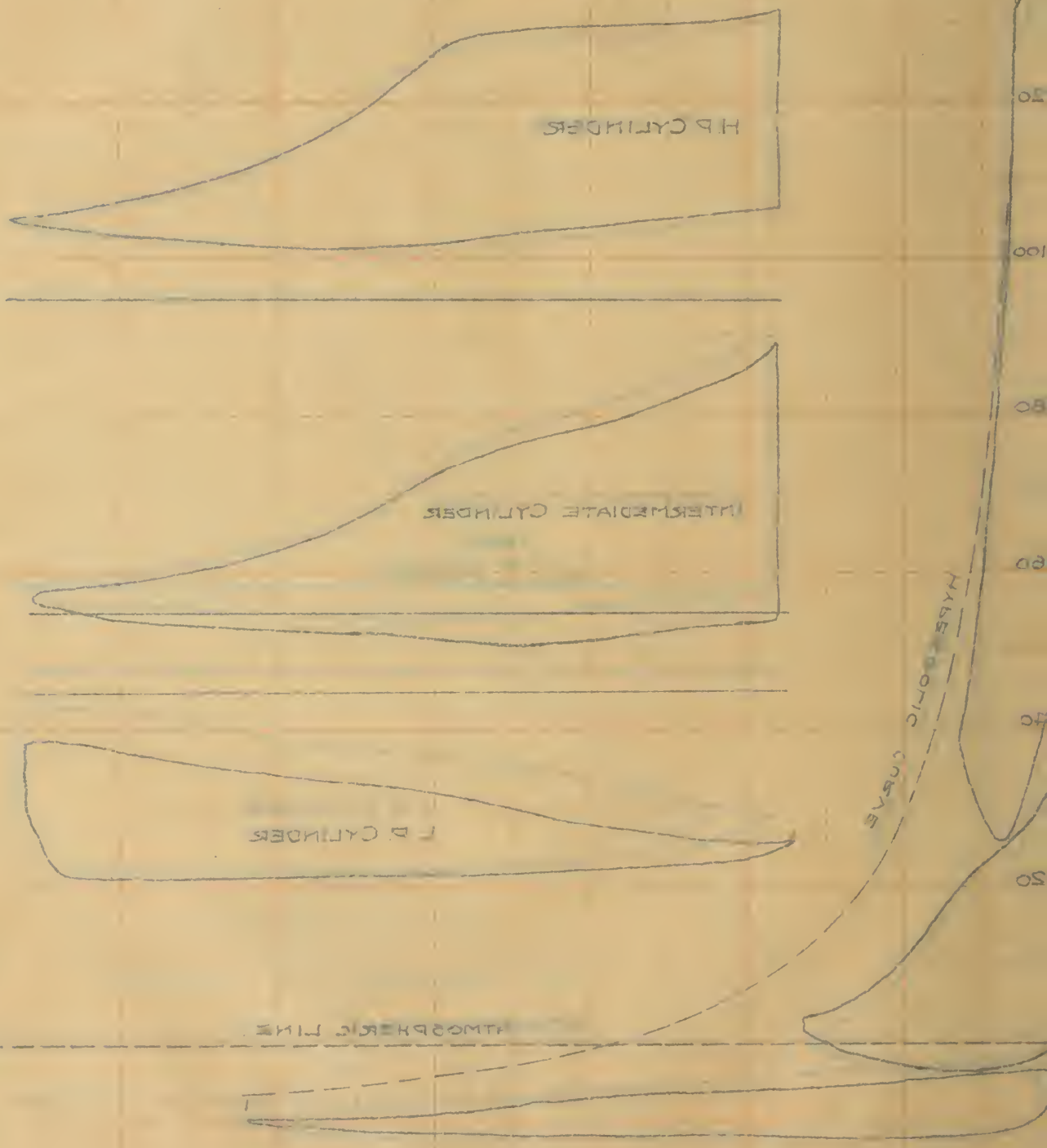


PLATE VI.

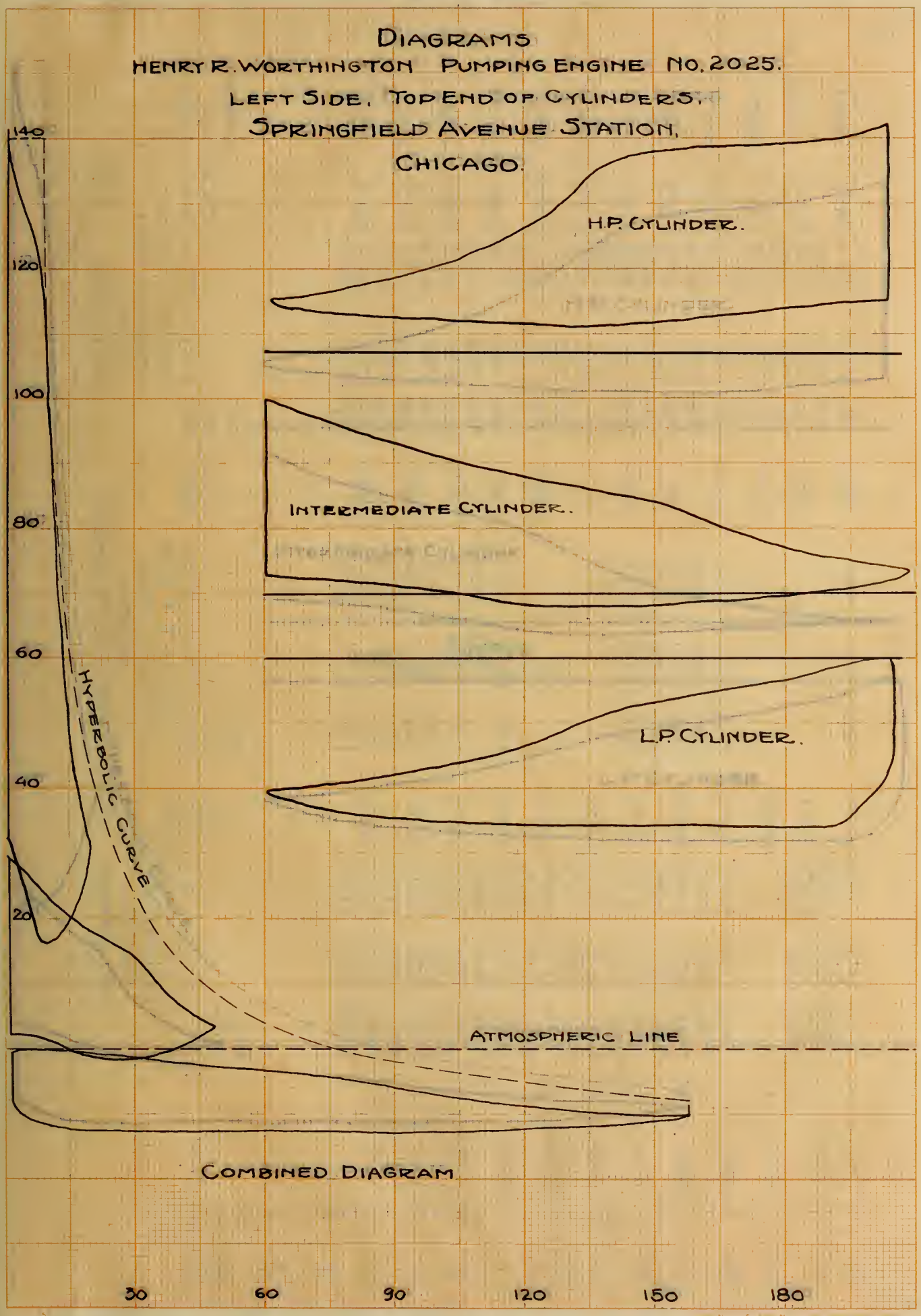

DIAGRAMS
HENRY R. WORTHINGTON PUMPING ENGINE NO. 2025.
LEFT SIDE. TOP END OF CYLINDERS.
SPRINGFIELD AVENUE STATION,
CHICAGO.
H.P. CYLINDER.
INTERMEDIATE CYLINDER.
L.P. CYLINDER.
HYPERBOLIC CURVE
ATMOSPHERIC LINE
COMBINED DIAGRAM
140
120
100
80
60
40
20
30
60
90
120
150
180

PLATE VI.

DIAGRAMS

HENRY R. WORTHINGTON PUMPING ENGINE No. 2025

LEFT SIDE, TOP END OF CYLINDERS.

SPRINGFIELD AVENUE STATION,

CHICAGO.

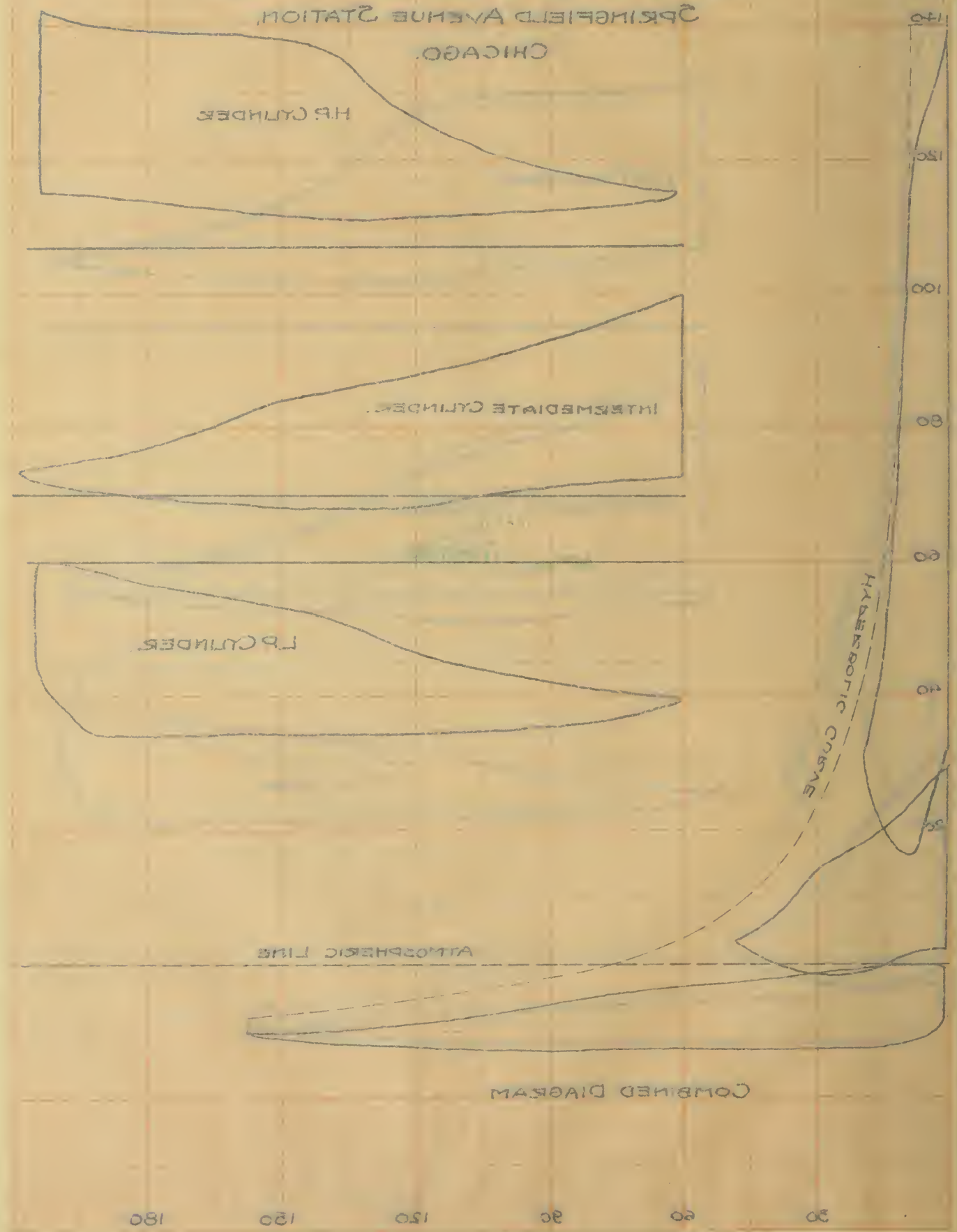
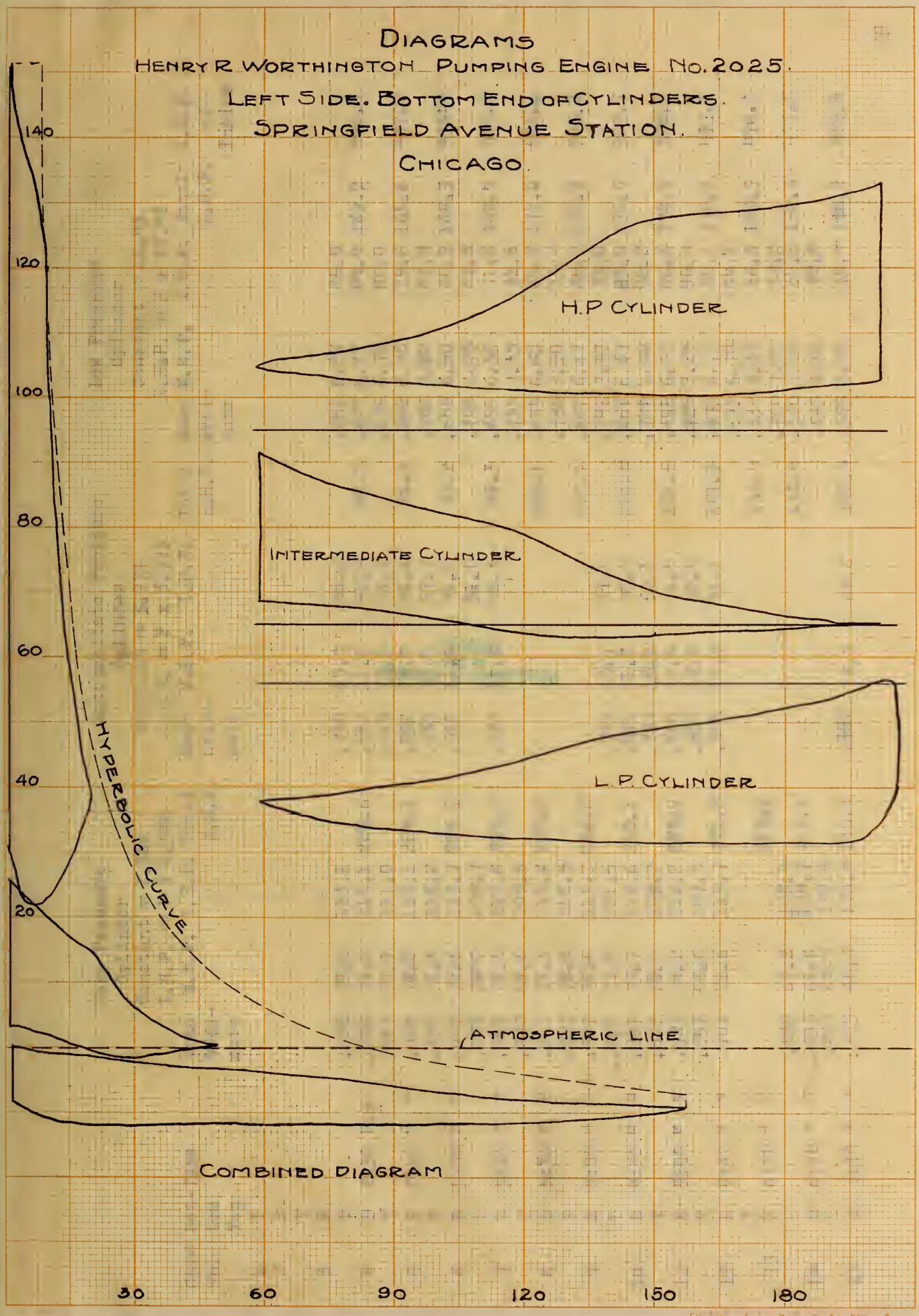
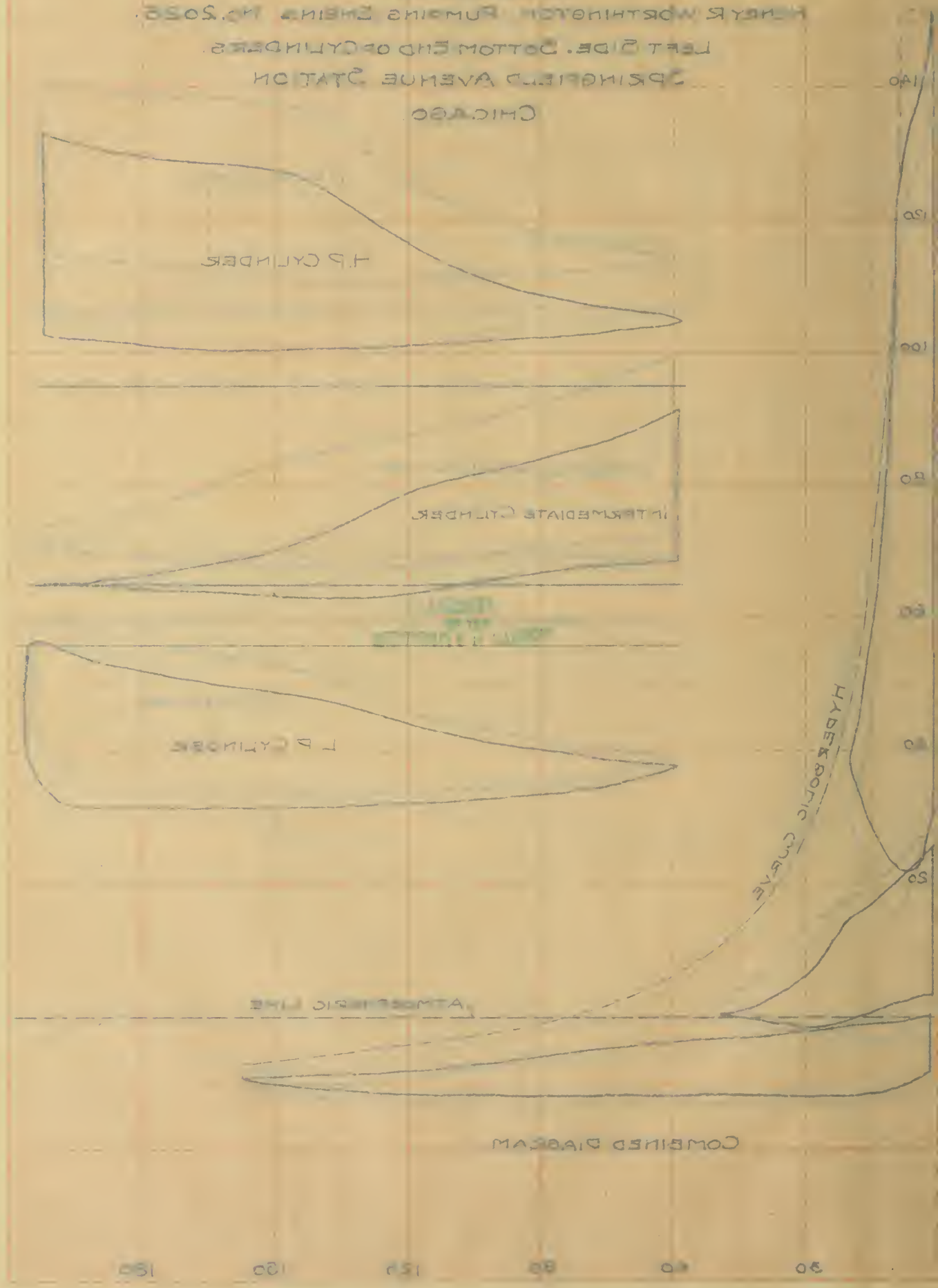


PLATE VII.


DIAGRAMS
HENRY R WORTHINGTON PUMPING ENGINE No. 2025.
LEFT SIDE. BOTTOM END OF CYLINDERS.
SPRINGFIELD AVENUE STATION.
CHICAGO.
140
120
100
80
60
40
20
H.P CYLINDER
INTERMEDIATE CYLINDER
L.P. CYLINDER
HYPERBOLIC CURVE
ATMOSPHERIC LINE
COMBINED DIAGRAM
30
60
90
120
150
180


H.P CYLINDER
INTERMEDIATE CYLINDER
L.P CYLINDER
HYPERBOLIC CURVE
ATMOSPHERIC LINE
COMBINED DIAGRAM
140
120
100
80
60
40
20
20
40
60
80
100
120
140

Card No.	Bottom Top	Time	High Pressure Cylinder Constant = 1.566 I.H.P. = P x 1.566 Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	Intermediate Pressure Cylinder Constant = 3.773 I.H.P. = P x 3.773 Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	Low Pressure Cylinder Constant = 12.43 I.H.P. = P x 12.43 Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	I.H.P. of Engine
1	T														
2	B														
	T														
3	B														
	T		.902	72.2	113.1		.750	15.0	56.6		.687	6.87	85.5		
4	B	2:30 P.M.	.890	71.2	115.1	224.6	.557	11.1	41.9	98.5	.677	6.77	84.4	169.9	493.0
	T		.887	70.9	111.0		.765	15.3	57.7		.675	6.75	84.0		
5	B	2:45 " "	.902	72.2	113.1	224.1	.552	11.0	41.6	99.3	.640	6.40	79.6	163.6	487.0
	T		.895	71.6	112.2		.765	15.3	57.7		.702	7.02	87.4		
6	B	3:00 " "	.907	72.6	113.7	225.9	.550	11.0	41.5	99.2	.650	6.50	80.9	168.3	493.4
	T		.875	70.0	109.7				51.0		.705	7.05	87.8		
7	B	3:15 " "	.917	73.0	114.8	224.5	.560	11.2	42.3	99.3	.655	6.55	81.6	169.4	493.2
	T		.870	69.6	109.5						.735	7.35	91.6		
8	B	3:30 " "	.917	73.3	114.7	224.2				100.1	.685	6.85	85.4	177.0	501.3
	T		.897	71.8	112.5						.750	7.50	93.4		
9	B	4:00 " "	.907	72.6	113.7	226.2				100.1	.687	6.87	85.5	178.9	505.2
	T		.890	71.2	111.5		.785	15.7	59.2		.747	7.47	93.0		
10	B	4:30 " "	.947	75.7	118.6	230.1	.565	11.2	42.4	101.6	.667	6.67	83.0	176.0	507.7
	T		.875	70.0	109.7		.797	15.9	60.1		.740	7.40	92.2		
11	B	5:00 " "	.927	74.2	116.2	225.9	.550	11.0	41.5	101.6	.695	6.95	86.6	178.8	506.3
	T		.857	68.6	107.5		.800	16.0	60.4		.725	7.25	90.4		
12	B	5:30 " "	.907	72.6	113.7	221.2	.545	10.9	41.1	101.5	.675	6.75	84.1	174.5	497.2
	T										.675	6.75	84.1		
13	B	6:00 " "				215.0				130.4	.537	5.37	66.8	150.9	496.3
	T		.865	69.2	108.4						.700	7.00	87.2		
14	B	6:30 " "	.835	66.8	104.7	213.1				130.4	.520	5.20	64.8	152.0	495.5
	T		.857	68.5	107.4						.665	6.65	82.8		
15	B	7:30 " "	.825	66.0	103.4	210.8	.912	18.2	68.8	130.4	.525	5.25	65.4	148.2	489.4

Card No.	Bottom Top	Time	Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	I.H.P. of Engine
	T		.832	66.6	104.4		.875	17.5	66.0		.697	6.97	86.8		
16	B	8:00 P.M.	.840	67.2	105.3	209.7	.770	15.4	58.1	124.1	.530	5.30	66.0	152.8	486.6
	T		.842	67.4	105.6		.852	17.1	64.4		.700	7.00	87.2		
17	B	8:30 P.M.	.825	66.0	103.4	209.0	.885	17.7	66.7	131.1	.530	5.30	66.0	153.2	493.3
	T		.850	68.0	106.5		.742	14.8	56.0		.705	7.05	87.2		
18	B	9:00 " "	.857	68.6	107.4	213.9	.917	18.3	69.2	125.2	.565	5.65	70.4	157.6	496.7
	T		.866	69.2	108.4		.827	16.5	62.4		.700	7.00	87.2		
19	B	9:30 " "	.840	67.2	105.3	213.7	.860	17.2	64.9	127.3	.562	5.62	70.0	157.2	498.2
	T		.852	68.2	106.8		.850	17.0	64.2		.700	7.00	87.2		
20	B	10:00 " "	.857	68.6	107.4	214.2	.895	17.9	67.5	131.7	.562	5.62	70.0	157.2	503.1
	T		.867	69.3	108.5		.920	18.4	69.4		.730	7.30	91.0		
21	B	10:30 " ".	.852	68.2	106.8	215.3	.860	17.2	64.9	134.3	.540	5.40	67.2	158.2	507.8
	T		.835	66.8	104.6		.855	17.1	64.5		.700	7.00	87.2		
22	B	11:00 " "	.870	69.6	109.0	213.6	.930	18.6	70.2	134.7	.570	5.70	71.0	158.2	506.5
	T		.860	68.8	107.5		.840	16.8	63.4		.700	7.00	87.2		
23	B	11:30 " "	.847	67.8	106.2	214.0	.915	18.3	69.0	132.4	.525	5.25	65.4	152.6	499.
	T		.857	68.6	107.4		.840	16.8	63.4		.715	7.15	89.1		
24	B	12- midnight	.850	68.0	106.5	213.9	.920	18.4	69.4	132.8	.565	5.65	70.4	159.5	506.2
	T		.925	74.0	115.9		.790	15.8	59.6		.710	7.10	88.4		
25	B	12:30 A.M.	.992	79.0	123.7	239.6	.552	11.1	41.7	101.3	.677	6.77	84.3	172.7	513.6
	T		.901	72.8	114.0		.792	15.8	59.7		.725	7.25	90.4		
26	B	1:00 " "	.995	76.4	119.7	233.7	.560	11.2	42.3	102.0	.675	6.75	84.1	174.5	510.2
	T		.922	73.7	115.4		.835	16.7	63.0		.722	7.22	90.0		
27	B	1:30 " "	.935	74.8	117.2	232.6	.550	11.0	41.5	104.5	.677	6.77	84.3	174.3	511.4
	T		.902	72.2	113.1		.790	15.8	59.6		.720	7.20	89.7		
28	B	2:00 " "	.900	72.0	112.8	225.9	.562	11.2	42.4	102.0	.680	6.80	84.6	174.3	502.2
	T		.905	72.4	113.4		.812	16.2	61.3		.725	7.25	90.4		
29	B	2:30 " "	.900	72.0	112.8	226.2	.555	11.1	41.9	103.2	.670	6.70	83.5	173.9	503.3
	T		.937	75.0	117.5		.837	16.7	63.1		.727	7.27	90.5		
30	B	3:00 " "	.935	74.8	117.2	234.7	.585	11.7	44.1	107.2	.680	6.80	84.7	175.2	517.1

Card No.	Bottom Top	Time	Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	I.H.P. of Engine
	T		.885	70.8	110.9		.808	16.2	61.0		.700	7.00	87.2		
31	B	3:30 A.M.	.900	72.0	112.7	223.6	.565	11.3	42.7	103.7	.660	6.60	82.2	169.4	496.7
	T		.857	68.6	107.4		.808	16.1	61.0		.702	7.02	87.4		
32	B	4:00 " "	.910	72.8	114.0	221.4	.585	11.7	44.1	105.1	.667	6.67	83.0	170.4	496.9
	T		.885	70.8	110.9		.832	16.7	63.2		.698	6.98	88.0		
33	B	4:30 " "	.			221.8	.545	10.9	41.1	104.3	.670	6.70	83.4	171.4	497.5
	T		.880	70.4	110.3		.847	16.9	63.9		.707	7.07	88.1		
34	B	5:00 " "	.927	74.1	116.0	226.3	.580	11.6	43.8	107.7	.660	6.60	82.1	170.3	504.3
	T		.852	68.2	106.8		.850	17.0	64.2		.705	7.05	87.8		
35	B	5:30 " "	.910	72.8	114.0	220.8	.587	11.7	44.3	108.5	.655	6.55	81.5	1169.2	498.5
	T		.847	67.8	106.2		.808	16.1	61.0		.677	6.77	84.3		
36	B	6:00 " "	.915	73.2	114.7	220.9	.565	11.3	42.6	103.6	.655	6.55	81.6	165.9	490.4
	T		.857	68.6	107.4		.832	16.6	62.8		.700	7.00	87.2		
37	B	6:30 " "	.892	71.4	111.8	219.2	.568	11.4	42.9	105.7	.652	6.52	81.2	168.4	493.3
	T		.855	68.4	107.2		.812	16.2	61.2		.677	6.77	84.4		
38	B	7:00 " "	.895	71.6	112.2	219.4	.557	11.2	42.1	103.3	.660	6.60	82.2	166.6	489.3
	T		.825	66.0	103.4		.845	16.9	63.8		.680	6.80	84.7		
39	B	8:00 "	.795	63.6	99.6	203.0	.862	17.2	65.0	128.8	.525	5.25	65.4	150.1	481.9
	T		.823	65.9	103.2		.847	16.9	63.9		.670	6.70	83.5		
40	B	8:30" "	.850	68.0	106.5	209.7	.891	17.8	67.2	131.1	.515	5.15	64.2	147.7	488.5
	T		.837	66.9	104.8		.870	17.4	65.6		.680	6.80	84.7		
41	B	9:00 " "	.850	68.0	106.5	211.3	.920	18.4	69.4	135.0	.512	5.12	63.8	148.5	494.8
	T		.827	66.1	103.6		.880	17.6	66.4		.680	6.80	84.7		
42	B	9:30 " "	.835	66.8	104.7	208.3	.920	118.4	69.4	135.8	.500	5.00	62.3	147.0	491.1
	T		.830	66.4	104.0		.852	17.0	64.3		.692	6.92	86.1		
43	B	10:00 " "	.822	65.8	103.1	207.1	.932	18.6	70.3	134.6	.515	5.15	64.2	150.3	492.0
	T		.840	67.2	105.2		.837	16.7	63.2		.695	6.95	86.5		
44	B	10:30 "" "	.837	66.9	104.8	210.0	.925	18.5	69.8	133.0	.512	5.12	63.8	150.3	493.3
	T		.840	67.2	105.2		.872	17.4	65.8		.677	6.77	84.4		
45	B	11:00 " "	.825	66.0	103.4	208.6	.937	18.7	70.7	136.5	.510	5.10	63.5	147.9	493.0
	T		.835	66.8	104.6	.	.860	17.2	64.8		.675	6.75	84.0		
46	B	11:30 " "	.842	67.4	105.5	210.1	.925	18.5	69.8	134.7	.517	5.17	64.4	148.4	493.2
	T		.800	64.0	100.2		.835	16.7	63.0		.675	6.75	84.0		
47	B	1:00 P.M.	.827	66.2	103.6	213.8	.935	18.7	70.6	133.6	.500	5.00	62.3	146.3	483.7

Card No.	Bot-Time tom Top	Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	Mean Ordinate	M.E.P.	I.H.P.	Total I.H.P.	I.H.P. of Engine
	T	.827	66.2	103.6		.830	16.6	62.6		.680	6.80	84.7		
48	B 1:30 P. M.	.827	66.2	103.6	207.2	.960	19.2	72.4	135.0	.487	4.87	60.6	145.3	487.5
	T	.827	66.2	103.6		.835	16.7	63.2		.675	6.75	84.1		
49	B 1:30 " "	.833	66.6	104.3	207.9	.747	14.9	56.4	119.6	.525	5.25	65.4	149.5	477.0
	T	..825	66.0	103.4		..818	16.4	61.8		.707	7.07	88.0		
50	B 1:35 " "	.832	66.5	104.1	207.5	.916	18.3	69.2	131.0	.522	5.22	65.0	153.0	491.5

Observers

C. B. Nolte - High Pressure Cylinder
Paul Burke - Intermediate Pressure Cylinder
E. C. Mc Millan - Low Pressure Cylinder

Cards 1 - 12 were taken from left side of engine
" 12 - 24 " " " right " " "
" 24 -- 38 " " " left " " "
" 38 - 50 " " " right " " "

Average I.H.P. for left side of engine = 500.00
" I.H.P. " right " " " = 493.58
Total average I.H.P. for engine = 993.58

Duty Test.

Springfield Ave. Pumping Station.

Pump No. E 2025
Oct. 1 & 2, 1908.

Engine Log No. I

No. of readings	Time	Revolution Counter	Counter Rev. pr. interval	Gauges Steam of engine	Vol.	Disch water pres.	Wall level	Temperatures Steam of engine	well
1	1.45	09317774.0		146.5	26.6	85	7.75	529	62
2	2.00	09318037.0	263.0	146.0	26.6	83	7.75	528	61
3	2.15	09318299.0	262.0	146.5	26.6	85	8.35	529	61
4	2.30	09318562.5	263.5	150.0	26.6	85	8.20	543	61
5	2.45	09318025.0	262.5	149.6	26.5	85	8.07	548	61
6	3.00	09319085.0	260.0	145.5	26.6	84	7.43	547	61
7	3.15	09319343.0	258.0	147.5	27.0	86	8.08	548	61
8	3.30	09319606.0	263.0	147.0	26.6	86	7.98	548	61
9	3.45	09319871.0	265.0	150.0	26.5	86.5	8.23	542	60
10	4.00	09320138.0	267.0	150.5	26.5	89	8.05	544	60
11	4.15	09320402.5	264.5	151.0	26.5	88	8.03	550	60
12	4.30	09320665.5	263.0	148.0	26.5	87	7.84	554	61
13	4.45	09320928.6	263.0	150.0	26.4	88.5	7.90	554	60
14	5.00	09321198.5	270.5	149.0	26.3	86	8.00	544	61
15	5.15	09321472.0	273.5	146.0	26.4	84.5	7.83	540	61
16	5.30	09321742.5	270.5	145.0	26.6	85	7.75	540	60
17	5.45	09322011.0	267.5	146.0	26.6	85	7.80	542	60
18	6.00	09322275.0	264.0	146.0	26.6	85	7.78	542	60
19	6.15	09322545.5	270.5	147.5	26.6	85	7.74	552	60
20	6.30	09322819.5	274.0	147.0	26.7	85.5	7.48	550	60
21	6.45	09323090.5	271.0	145.0	26.7	84	7.41	550	61
22	7.00	09323365.0	274.5	148.0	26.7	85	7.50	555	61
23	7.15	09323645.0	280.0	150.0	26.8	84	7.40	560	60
24	7.30	09323913.0	268.0	150.0	26.7	86	7.50	558	60
25	7.45	09324186.5	273.5	151.0	26.7	86.5	7.76	560	61
26	8.00	09324458.5	272.0	148.	26.6	88	7.40	542	61
27	8.15	09324727.5	269.0	147	26.7	85.5	7.40	548	61
28	8.30	09324991.5	264.0	145	26.7	87	7.40	550	61
29	8.45	09325256.0	264.5	145	26.7	86	7.40	548	60
30	9.00	09325517.5	261.5	147	26.7	88.5	7.42	550	61
31	9.15	09325782.0	264.5	145	26.7	86.5	7.40	542	60
32	9.30	09326045.5	263.5	143	26.6	86.5	7.40	544	61
33	9.45	09326307.5	262.0	147	26.6	88	7.40	544	61
34	10.00	09326571.0	263.5	145	26.7	88	7.40	542	61
35	10.15	09326830.5	259.5	147	26.7	88	7.40	547	61
36	10.30	09327089.5	259.0	150	26.6	89.5	7.40	544	61
37	10.45	09327347.5	258.0	146	26.6	89.5	7.40	540	61
38	11.00	09327607.5	260.0	149	26.6	88.5	7.40	543	61
39	11.15	09327874.5	267.0	146	26.6	88	7.40	544	61
40	11.30	09328138.0	263.5	148	26.6	89	7.40	540	61
41	11.45	09328404.0	266.0	149	26.6	89	7.40	536	61
42	12.00	09328668.0	264.0	147	26.6	89	7.40	528	61
43	12.15	09328933.5	265.5	149	26.4	89	7.40	534	61
44	12.30	09329201.0	267.5	149	26.4	89	7.40	544	61
45	12.45	09329471.0	270.0	146	26.9	89	7.40	548	61
46	1.00	09329732.0	261.0	149	26.9	89	7.40	550	61

Duty Test (cont)

Springfield Ave. Pumping Station

Pump No. E 2025
Oct. 1 & 2 , 1908.

Engine Log No. 1

No. Of readings	Time	Revolution Counter	Counter Rev. pr. interval	Gauges Steam of engine	Vac	Disch Water pres.	Wall level	Temperatures Steam of engine	Well
47	1.15	09329999.0	267.0	146	26.9	89	7.40	543	61
48	1.30	09330264.0	265.0	149	26.9	89	7.50	540	61
49	1.45	09330526.0	262.0	145	26.8	89	7.50	538	61
50	2.00	09330780.0	254.0	144	26.9	89	7.50	537	61
51	2.15	09331039.5	259.5	145	26.9	89	7.50	538	61
52	2.30	09331293.0	253.5	145	26.9	89	5.25	538	61
53	2.45	09331552.0	259.0	145	26.9	88	5.20	536	60
54	3.00	09331812.0	265.0	146	26.8	89	5.80	540	61
55	3.15	09332083.5	266.5	146	26.8	89	5.29	540	60
56	3.30	09332340.0	256.5	145	26.8	89	5.24	529	61
57	3.45	09332599.0	259.0	148	26.8	89	5.70	532	61
58	4.00	09332862.0	263.0	150	26.7	89	5.60	540	61
59	4.15	09333121.0	259.0	147	26.7	89	5.25	538	61
60	4.30	09333376.5	255.5	147	26.7	89	5.58	533	61
61	4.45	09333636.0	259.5	145	26.8	89.0	5.35	535	61
62	5.00	09333898.0	262.0	146	26.7	89.	5.45	536	61
63	5.15	09334170.0	272.0	145	26.8	87	5.70	536	61
64	5.30	09334438.0	268.0	148	26.8	88	6.30	532	61
65	5.45	09334708.0	270.0	142.5	26.8	86.5	6.50	542	61
66	6.00	09334976.0	268.0	145	26.8	86.5	6.00	546	61
67	6.15	09335249.0	273.0	145	26.8	86.0	7.01	544	61
68	6.30	09335532.0	283.0	148	26.8	85.5	7.56	542	61
69	6.45	09335812.5	280.5	146	26.8	84.0	7.89	535	61
70	7.00	09336091.0	278.5	145	26.8	84.5	7.84	540	61
71	7.15	09336355.0	264.0	145	26.9	84.5	7.98	532	61
72	7.30	09336628.0	273.0	145	26.8	85.0	8.05	530	61
73	7.45	09336894	266.0	145	26.8	85.0	8.33	543	61
74	8.00	09337164	270.0	148	26.8	86.0	8.72	546	61
75	8.15	09337433	269.0	147	26.8	85.0	8.60	542	61
76	8.30	09337707	274.0	146	26.8	85.0	8.40	547	60
77	8.45	09337979.0	272.0	146	26.8	85.0	8.51	540	60
78	9.00	09338252.0	273.0	147	26.8	85.5	8.60	543	60
79	9.15	09338522.0	270.0	147	26.8	85.5	8.52	548	60
80	9.30	09338796.0	274.0	145	26.8	85.5	8.50	549	60
81	9.45	09339073.0	277.0	147	26.8	85.5	8.49	544	60
82	10.00	09339346.0	273.0	145	26.8	85.5	8.40	546	60
83	10.15	09339614.0	268.0	146	26.8	85.5	8.30	538	60
84	10.30	09339883.0	269.0	145	26.8	85.5	8.34	548	60
85	10.45	09340154.0	271.0	149	26.8	86.5	8.65	561	60
86	11.00	09340426.0	272.0	143	26.8	85.5	8.05	562	60
87	11.15	09340697.0	271.0	147	26.8	86.0	8.39	554	60
88	11.30	09340968.0	271.0	147	26.8	85.5	8.35	552	60
89	11.45	09341241.0	273.0	146	26.8	85.5	8.33	550	61
90	12.00	09341515.0	274.0	148	26.8	85.5	8.52	546	61
91	12.15	09341781.0	266.0	146	26.8	85.5	8.25	545	61
92	12.30	09342049.0	269.0	147	26.8	85.5	8.12	546	61
93	12.45	09342312.0	263.0	143	26.8	85.0	8.00	536	60

Duty Test (cont)

Springfield Ave. Pumping Station Pump No. E 2025

No. of readings	Time	Revolution Counter	Engine Counter Rev. pr. interval	Log Steam of engine	No. I Gauges Voc.	Disch. water pres.	Well level	Temperatures Steam of engine	Well
94	1.00	09342584.0	272.0	150	26.8	85.5	8.48	551	60
95	1.15	09342848.0	264.0	149	26.8	85.5	8338	548	61
96	1.30	09343114.0	266.0	151	26.8	86.0	8.60	550	61
97	1.45	09343379.0	265.0	148	26.8	85.5	8.32	552	61
			266.6	147	26.7	186.68	7.45	543	60.68

Correction due to
13.48 ft. water col. on Steam ga. 5.
5.84
Av. Steam Pres. 141.16

Log of Observers :

1.45 P.M.	- 6.00 P M	Haynes,	Golden
6.00	- 6.30	Golden	------
6.30	- 7.15	Haynes	------
7.15	- 9.00	Haynes	Golden
9.00	- 4.30 A.M.	Martin	Halpin
4.30 A.M.	- 6.45	Martin	Nicholson
6.45	- 7.30	Martin	-------
7.30	- 83.0	Martin	Nicholson
8.30	- 11.15	Martin	Nicholson
11.15	- 12.00	Martin	-----
12.00	- 12.35P.M.	Nicholson	----
12.35 P.M.	- 1.45	Martin,	Nicholson

Duty Test

Springfield Ave. Pumping Station

Pump No. E 2025
Oct. 12 2, 1908.

Engine Log No. 2

No. of readings	Time	Gauges Receivers 1st.	Receivers 2nd.	Reheater Coil	L.P. Jacket	Balance Pres.	Acc. Back Pres.	Stroke Shortag No.1 side Up	No.1 side Down	No.2 side Up	No.2 side Down
1	1.45	29	.5	91	17.5	101	13.5	0	1/8	0	1/8
2	2.00	29	.5	90	17.5	107	13.5	1/8	3/4	1/8	5/8
3	2.15	31	1.2	90	18	107	13.7	0	1/2	0	1/4
4	2.30	30	1.2	102	16	107	13.4	0	1/8	0	1/8
5	2.45	30	1.2	103	15	106	13.3	1/8	1/8	1/8	1/8
6	3.00	29	1.2	103	13	106	13.7	0	1/8	0	1/8
7	3.15	31	1.2	103	14	106	13.7	0	1/8	0	1/4
8	3.30	31	1.2	103	13	105	13.7	1/4	1/8	1/4	1/8
9	3.45	32	1.2	102	12.5	106	13.6	1/8	1/8	0	1/8
10	4.00	32	2.0	105	12	105	13.6	1/4	1/8	1/8	1/4
11	4.15	31.5	2.0	106	12	105	13.7	1/4	1/8	1/8	1/4
12	4.30	31	1.2	106	12	104	13.7	1/4	1/4	1/4	3/8
13	4.45	32	1.5	106	12	104	13.6	1/4	1/8	1/4	3/8
14	5.00	31	1.5	105	12	104	13.6	1/4	1/8	1/4	1/4
15	5.15	31	1.5	101	12	105	13.5	1/4	1/4	1/8	1/4
16	5.30	30	1.5	103	12	105	13.5	3/8	1/4	3/8	1/4
17	5.45	30	1.2	103	12	105	13.6	1/4	1/4	1/4	1/8
18	6.00	30	1.5	102	12	103	13.6	3/8	1/4	3/8	1/4
19	6.15	30	1.5	105	12	104	13.6	3/8	1/8	1/4	1/8
20	6.30	31	1.5	105	12	106	13.7	3/8	1/8	1/4	1/8
21	6.45	30	1.5	102	12	105	13.7	1/4	1/8	1/8	1/8
22	7.00	31	1.5	103	12	105	13.7	1/4	1/8	1/4	1/8
23	7.15	30	1.5	103	12	111	13.5	1/4	1/8	1/4	1/8
24	7.30	31	1.5	104	12	110	13.7	1/4	1/8	1/4	1/8
25	7.45	30	1.5	103	12	110	13.7	1/8	1/4	1/8	1/4
26	8.00	31	1.5	105	12	105	13.5	1/8	1/8	1/8	1/4
27	8.15	31	1.5	104	12	107	13.5	0	3/8	1/8	1/4
28	8.30	30	1.5	103	12	110	13.7	0	3/8	0	1/4
29	8.45	30	1.5	104	12	108	13.6	0	3/8	0	3/8
30	9.00	30	1.5	105	12	109	13.7	0	1/4	0	0
31	9.15	30.0	1.5	103	12	110	13.8	0	3/8	0	1/4
32	9.30	29.5	1.5	103	12	113	13.6	0	1/8	0	1/4
33	9.45	30	1.5	104	12	114	14.2	1/8	3/8	0	1/8
34	10.00	30	1.5	104	12	108	14.2	1/8	1/4	0	0
35	10.15	30	1.5	106	12	107	14.8	1/8	1/4	1/8	1/8
36	10.30	30	1.5	106	12	106	14.5	0	1/4	1/8	1/8
37	10.45	30	1.5	106	12	108	13.9	0	1/8	0	1/4
38	11.00	30	2.0	106	12	106	14.2	0	1/4	0	1/8
39	11.15	30	2.0	105	12	106	14.0	0	1/4	0	1/4
40	11.30	30	2.0	105	12	107	14.0	0	1/4	0	1/4
41	11.45	31	2.0	105	12	106	14.0	0	1/4	0	1/4
42	12.00	31	2.0	105	12	106	14.0	0	1/4	0	1/4
43	12.15	31	2.0	105	12	106	14.0	0	1/8	0	1/4

Duty Test (cont)

Springfield Ave. Pumping Station

Pump No. E 2025
Oct. 1& 2 , 1908.

Engine Log. No.2

No. of Reading	Time	Receivers 1st	Receivers 2nd	Gauges Reheater Coils	L.P. Jacket	Balance Pres	Acc. Back Pres.	Stroke Shortage No. 1 Up	No. 1 Side Down	No. 2 Up	No. 2 side Down
44	12.30	31	2.0	104	12	106	14.6	0	1/8	0	1/8
45	12.45	31	2.0	104	12	107	14.3	0	1/4	0	1/4
46	1.00	31	2.0	105	12	107	14.8	0	1/4	0	1/8
47	1.15	31	2.0	106	12	106	14.5	1/8	1/4	1/4	3/8
48	1.30	31	1.7	106	12	106	14.2	0	1/8	0	1/8
49	1.45	30	1.7	105	12	106	13.9	0	1/4	1/8	3/8
50	2.00	30	1.7	104	12	106	13.8	0	1/4	0	3/8
51	2.15	30	1.7	104	11.5	106	13.9	0	1/8	1/8	3/8
52	2.30	30	1.7	104	11.5	105	14.3	0	0	1/8	1/4
53	2.45	30	1.7	103	11.5	105	14.4	1/8	1/8	0	1/8
54	3.00	32	1.8	104	11.3	108	15.3	0	1/8	0	3/8
55	3.15	31	1.2	105	11.0	107	14.9	0	1/4	0	3/8
56	3.30	30	1.3	103	11.0	107	14.2	0	1/8	1/8	1/4
57	3.45	31	1.3	104	11.0	106	14.6	0	1/8	0	1/2
58	4.00	31	1.3	105	11.0	106	14.9	0	3/8	1/8	1/8
59	4.15	31	1.1	104	11.0	106	14.9	0	1/4	1/8	1/8
60	4.30	31	1.0	104	11.0	105	14.2	0	1/4	1/8	1/4
61	4.45	30	1.0	102	11.5	105	14.6	0	1/4	1/8	1/4
62	5.00	31	1.1	101	11.5	105	15.0	0	1/4	0	1/4
63	5.15	31	1.0	100	11.5	107	14.8	0	3/8	0	3/8
64	5.30	31.5	1.0	100	11.5	106	15.0	0	1/4	0	1/4
65	5.45	30	1.0	100	11.7	106	14.7	0	1/8	1/8	1/4
66	6.00	30	1.0	100	12.0	107	14.8	0	1/8	1/8	0
67	6.15	30	1.0	100	12.0	107	14.4	0	1/4	0	1/4
68	6.30	32	1.0	100	12.0	107	14.3	1/8	1/4	0	1/4
69	6.45	32	1.0	100	12.0	107	13.8	0	1/8	0	1/8
70	7.00	31	1.0	100	12.0	106	13.8	0	1/4	0	1/8
71	7.15	31	1.0	100	12.0	106	14.2	0	1/8	0	1/4
72	7.30	31	1.0	100	11.8	106	13.6	0	3/8	0	1/4
73	7.45	31	1.0	100	12.0	106	13.7	0	1/8	0	0
74	8.00	32	2.5	100	12.0	106	13.4	0	1/8	0	0
75	8.15	32	2.0	100	12.0	105	13.6	0	1/8	0	0
76	8.30	31	2.0	100	12.0	105	13.6	0	0	0	0
77	8.45	30	1.3	100	12.0	105	13.5	0	1/8	0	1/8
78	9.00	31	1.3	100	12.0	105	13.8	0	1/8	0	1/8
79	9.15	31	1.8	100	12.0	104	13.8	0	0	0	0
80	9.30	31	1.3	100	12.0	104	14.2	0	0	0	1/8
81	9.45	32	2.0	100	12.0	104	14.1	0	1/8	0	1/8
82	10.00	31	1.3	100	12.0	104	14.0	0	1/8	0	1/8
83	10.15	31	1.3	100	12.0	104	14.0	0	0	0	0
84	10.30	31	1.3	100	12.0	104	14.0	1/8	0	0	0
85	10.45	32	1.3	102	12.5	104	14.5	1/8	1/4	0	1/8
86	11.00	31	1.3	100	12.5	105	14.3	1/8	1/8	1/8	1/4
87	11.15	32	1.3	102	12.5	105	14.0	0	0	0	1/8
88	11.30	31	1.3	102	12.5	105	13.9	1/8	1/4	0	1/8

Duty Test (cont)

Springfield Ave. Pumping Station — Pump E 2025

Oct. 2, 1908

Engine Log No. 2

No. of readings	Time	Gauges: Receivers 1st	Receivers 2nd	Reheater coils	J.P. Jacket	Balance Pres.	Acc. Back Pres.	Stroke Shortage: No. 1 side Up	No. 1 side Down	No. 2 side Up	No. 2 side Down
89.	11.45	31	1.3	102	12.5	105	13.8	0	1/8	0	1/8
90	12.00	31	1.3	103	12.5	104	13.8	1/8	1/4	1/8	1/4
91	12.15	31	1.3	103	13.0	104	13.5	0	1/8	1/8	1/4
92	12.30	31	2.0	103	13.0	104	13.5	1/8	1/8	1/8	1/4
93	12.45	30	1.5	101	13.0	104	13.6	0	1/8	0	1/8
94	1.00	31	1.3	103	13.0	104	13.5	0	1/8	0	1/8
95	1.15	31	1.3	103	13.0	104	13.5	0	1/8	0	0
96	1.30	31	1.5	105	13.0	102	14.0	1/8	1/4	0	0
97	1.45	31	1.5	105	13.0	104	13.9	0	1/4	0	0
Average		31.0	1.46	103	12.8	106	14.1			0.513	

Log of Observers.

1.45 P.M. - 5.00 P.M.	Palmer, McCarty
5.00 P.M. - 6.00 P.M.	McCarty, Olsen
6.00 P.M. - 6.30 P.M.	McCarty ------
6.30 P.M. - 7.10 P.M.	Olsen
7.10 P.M. - 9.00 P.M.	Palmer, McCarty
9.00 P.M. - 4.30 A.M.	Persons, Heyne
4.30 A.M. - 6.45 A.M.	Persons, O'Bryne
6.45 A.M. - 7.30 A.M.	O'Bryne -----
7.30 A.M. - 8330 A.M.	Persons
8.30 A.M. -12.00 A.M.	O'Byrne
12.00A.M. -12.40 P.M.	Persons -----
12.40 P.M. - 1.45 P.M.	Persons, O'Byrne

Duty Test

Springfield Ave. Pumping Station — Pump No. E 2025

Oct. 1, 1908.

Log of Condensed Steam

No. of read'g	Temp. condensed steam	Time	Barrel No. 1 Tare	Barrel No. 1 Gross	Barrel No. 1 Net	Barrel No. 2 Time	Barrel No. 2 Tare	Barrel No. 2 Gross	Barrel No. 2 Net
	63 F	1 .55 P.M.	355	1244	889	1.50	341	1262	921
	63 F	2.05 " "	376	1332	956	2.00	320	1131	811
	63 F	3.47 " "	347	1183	836	2.10	336	1234	898
	63 F	2.25 " "	358	1236	878	2.20	313	1278	965
	63 F	2.35 " "	358	1317	959	2.30	313	1200	887
	70 F	2.45 " "	353	1030	677	2.40	321	1206	885
	63 F	2.55 " "	430	1293	863	2.50	424	1266	842
	63 F	3.05 " "	437	1326	889	3.00	416	1206	790
	63 F	3.15 " "	448	1286	838	3.10	385	1227	842
	63 F	3.25 " "	447	1344	897	3.20	443	1376	933
	63 F	3.35 " "	445	1358	913	3.30	446	1291	845
	70 F	3.45 " "	445	1352	907	3.40	466	1336	870
	63 F	3.55 " "	438	1337	899	3.50	444	1351	907
	63 F	4.05 " "	426	1362	936	4.00	425	1339	914
	68 F	4.15 " "	463	1337	874	4.10	431	1292	861
	68 F	4.25 " "	444	1297	853	4.20	436	1387	951
	68 F	4.35 " "	443	1390	947	4.30	424	1250	826
	70 F	4.45 " "	437	1250	813	4.40	431	1334	903
	70 F	4.55 " "	450	1347	897	4.50	426	1400	974
	69 F	5.05 " "	449	1460	1011	5.00	451	1284	833
	68 F	5.15 " "	444	1272	828	5.10	433	1315	882
	71 F	5.25 " "	442	1298	856	5.20	425	1383	958
	68 F	5.35 " "	459	1429	970	5.30	441	1216	775
	67 F	5.45 " "	447	1220	773	5.40	444	1292	848
	70 F	5.55 " "	450	1265	815	5.50	434	1379	945
	67 F	6.05 " "	446	1367	921	6.00	436	1180	744
	74 F	6.15 " "	446	1214	768	6.10	428	1347	919
	68 F	6.25 " "	446	1368	922	6.20	427	1370	943
	65 F	6.35 " "	441	1348	907	6.30	431	1228	797
	68 F	6.45 " "	446	1239	793	6.40	424	1310	886
	65 F	6.55 " "	451	1384	933	6.50	427	1338	911
	65 F	7.05 " "	438	1297	859	7.00	430	1231	811
	72 F	7.15 " "	380	1214	834	7.10	326	1293	967
	68 F	7.25 " "	365	1404	1039	7.20	325	1297	972
	67 F	7.35 " "	380	1312	932	7.30	332	1103	771
	70 F	7.45 " "	377	1229	852	7.40	319	1253	934
	65 F	7.55 " "	367	1370	1003	7.50	325	1251	926
	63 F	8.05 " "	433	1427	994	8.00	375	1162	787
	64 F	8.15 " "	455	1252	797	8.10	432	1254	822
	65 F	8.25 " "	454	1378	924	8.20	424	1370	946
	65 F	8.35 " "	452	1374	922	8.30	427	1192	765
	63 F	8.45 " "	448	1280	832	8.40	381	1332	951
	60 F	8.55 " "	455	1312	857	8.50	418	1309	891

Duty Test (cont)

Springfield Ave. Pumping Station — Pump No. E 2025

Oct. 1, 1908.

Log of Condensed Steam

No. of read'g	Temp. condensed steam	Time	Barrel No. 1 Tare	Barrel No. 1 Gross	Barrel No. 1 Net	Barrel No. 2 Time	Barrel No. 2 Tare	Barrel No. 2 Gross	Barrel No. 2 Net
	69 F	9.05 P.M.	442	1282	840	9.00	424	1322	898
	67 F	9.15 " "	456	1341	885	9.10	431	1353	922
	70 F	9.25 " "	451	1387	936	9.20	411	1386	975
	68 F	9.35 " "	450	1351	901	9.30	402	1150	748
	71 F	9.45 " "	447	1261	814	9.40	435	1377	942
	65 F	9.55 " "	451	1400	949	9.50	435	1319	884
	68 F	10.05 " "	451	1318	867	10.00	430	1272	842
	69 F	10.15 " "	451	1318	860	10.10	438	1335	897
	69 F	10.25 " "	453	1360	907	10.20	375	1362	987
	66 F	10.35 " "	453	1353	900	10.30	445	1200	755
	70 F	10.45 " "	451	1255	804	10.40	410	1418	1008
	71 F	11.05 " "	478	1335	857	10.50	433	1327	894
	71 F	11.05 " "	453	1470	1017	11.00	432	1222	790
	69 F	11.05 " "	455	1217	762	11.10	423	1335	912
	64 F	11.25 " "	445	1267	822	11.20	438	1360	922
	72 F	11.35 " "	458	1355	897	11.30	433	1176	743
	71 F	11.45 " "	442	1481	1039	11.40	423	1336	913
	73 F	11.55 " "	449	1356	907	11.50	425	1316	891
	68 F	12.05 " "	445	1351	906	12.00	434	1352	918
	68 F	12.15 " "	454	1340	886	12.10	423	1390	967
	64 F	12.25 " "	440	1379	939	12.20	430	1415	985
	65 F	12.35 " "	441	1347	906	12.30	405	1214	809
	67 F	12.45 " "	453	1337	884	12.40	430	1335	905
	70 F	12.55 " "	449	1331	882	12.50	422	1258	836
	64 F	1.05 " "	447	1325	878	1.00	425	1362	937
	63 F	1.15 " "	441	1360	919	1.10	427	1407	980
	61 F	1.25 " "	440	1300	860	1.20	436	1358	922
	61 F	1.35 " "	437	1214	777	1.30	425	1315	890
	66 F	1.45 " "	441	1144	703	1.40	432	1108	676
	60 F	1.55 " "	439	1185	746	1.50	425	1121	696
	64 F	2.05 & "	434	1167	733	2.00	426	1043	617
	70 F	2.15 " "	456	1245	789	2.10	412	1349	937
	65 F	2.25 " "	442	1274	832	2.20	424	1314	890
	61 F	2.35 " "	447	1392	945	2.30	423	1208	785
	65 F	2.45 " "	444	1202	758	2.40	394	1207	813
	70 F	2.55 " "	443	1345	902	2.50	427	1288	861
	62 F	3.05 " "	445	1467	1022	3.00	429	1325	896
	68 F	3.15 " "	449	1286	837	3.10	437	1299	862
	70 F	3.25 " "	459	1287	828	3.20	440	1352	912
	60 F	3.35 " "	451	1420	969	3.30	445	1233	788
	70 F	3.45 " "	444	1309	865	3.40	432	1267	835
	69 F	3.55 " "	438	1290	852	3.50	432	1354	922
	65 F	4.05 " "	444	1260	816	4.00	438	1341	903
	59 F	4.15 " "	446	1257	811	4.10	426	1354	928
	68 F	4.25 " "	438	1229	791	4.20	430	1299	869

Duty Test (cont)

Springfield Ave., Pumping Station

Pump No. E 2025
Oct. 1st 1908

Log of Condensed Steam

No. of read'g	Temp. condensed steam	Time	Tare	Gross	Net	Time	Tare	Gross	Net
	66	4.35	439	1337	898	4.30	423	1272	849
	70	4.45	454	1230	776	4.40	435	1300	860
	68	4.55	446	1330	884	4.50	451	1320	865
	68	5.05	418	1422	1004	5.00	430	1221	791
	67	5.15	437	1232	795	5.10	437	1334	897
	67	5.25	455	1330	875	5.20	437	1378	941
	67	5.35	445	1387	942	5.30	430	1280	850
	64	5.45	445	1283	838	5.40	395	1248	853
	65	5.55	426	1355	929	5.50	433	1314	881
	72	6.05	444	1334	890	6.00	432	1371	939
	65	6.15	446	1265	819	6.10	431	1316	885
	70	6.25	446	1357	911	6.20	423	1404	981
	66	6.35	435	1411	976	6.30	422	1318	896
	69	6.45	440	1320	880	6.40	424	1340	916
	70	6.55	441	1442	1001	6.50	425	1297	872
	65	7.05	445	1335	890	7.00	423	1225	802
	69	7.15	438	1251	813	7.10	424	1266	842
	65	7.25	447	1300	853	7.20	432	1405	973
	67	7.35	443	1334	891	7.30	426	1283	857
	65	7.45	450	1244	794	7.40	425	1294	869
	60	7.55	451	1343	892	7.50	429	1290	861
	65	8.05	388	1266	878	8.00	339	1223	884
	75	8.15	382	1144	762	8.10	304	1236	932
	64	8.25	421	1355	934	8.20	350	1266	916
	63	8.35	439	1292	853	8.30	408	1273	865
	65	8.45	436	1267	831	8.40	438	1365	927
	65	8.55	445	1331	886	8.50	395	1387	992
	64	9.05	446	1429	983	9.00	451	1239	788
	66	9.15	452	1268	816	9.10	442	1315	873
	68	9.25	449	1440	991	9.20	431	1403	972
	71	9.35	448	1431	983	9.30	435	1229	794
	71	9.45	453	1232	779	9.40	436	1376	940
	65	9.55	450	1360	910	9.50	427	1330	923
	66	10.05	430	1319	889	10.00	432	1210	778
	67	10.15	447	1338	891	10.10	423	1220	797
	67	10.25	453	1293	840	10.20	426	1377	950
	65	10.35	463	1270	807	10.30	446	1227	781
	69	10.45	446	1277	831	10.40	443	1294	851
	66	10.55	452	1254	802	10.50	430	1468	1038
	65	11.05	451	1464	1013	11.00	394	1196	802
	65	11.15	449	1221	772	11.10	434	1272	838
	66	11.25	450	1283	833	11.20	451	1455	1004
	66	11.35	458	1488	1030	11.30	435	1182	747
	65	11.45	447	1208	761	11.40	436	1323	887
	65	11.55	454	1328	874	11.50	426	1455	1029

Duty Test (cont)

Springfield Ave. Pumping Station Pump No E 2025

Oct. 1, 1908

Log of Condensed Steam

No. of read'g	Temp. condensed steam	Time	Barrel No. 1 Tare	Gross	Net	Barrel No.2 Time	Tare	Gross	Net
	72	12.05	441	1310	869	12.00	417	1273	856
	68	12.15	446	1257	811	12.10	428	1330	902
	70	12.25	440	1332	892	12.20	430	1405	975
	64	12.35	442	1155	713	12.30	436	1249	813
	64	12.45	442	1245	803	12.40	432	1361	929
	64	12.55	446	1173	727	12.50	424	1365	941
	65	1.05	438	1323	885	1.00	403	1328	925
	63	1.15	442	1224	782	1.10	430	1286	856
	60	1.25	459	1356	897	1.20	426	1453	1027
	60	1.35	448	1505	1057	1.30	441	1200	759
	65	1.45	445	1179	734	1.40	428	1258	830
Average	66.6								

Total Condensed Steam 252415 lbs.

Observers

1.45 - 5.00	Boesch	, Olsen
5.00 p 6.30	Boesch	Palmer
6.30 - 7.10	_____	Palmer
7.10 - 8.40	Boesch	_____
8.40 - 8.45	Boesch	Akeson
8.45 - 4.30A.M.	"	Akeson
4.30 - 6.45	Boesch	Carlson
6.45 - 7.30	Boesch	Carlson
7.30 - 8.30	Boesch	_____
8.30 - 11.15	Boesch	Carlson
11.15 - 11.55	_____	Carlson
11.55 - 12.25	Boesch	_____
12.25 - 1.45	Boesch	Carlson